Distr.
LIMITED

UNIDO/IO.598
28 September 1984

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Seminar on the Production of
High Quality Cotton Knitgoods*
US/INT/82/234

Manchester, United Kingdom, 2-6 April 1984

REPORT**

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* Organized by the International Institute for Cotton (IIC) and the United Nations Industrial Development Organization (UNIDO).

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FOREWORD

This report presents the papers and summarizes the discussions at a Seminar on "The Production of High Quality Cotton Knitgoods", held in Manchester, England during the week of April 2nd-6th, 1984. The seminar was the first element of a project (US/INT/82/234) financed by the United Nations Industrial Development Organization (UNIDO) from the UK Government's contribution to the United Nations Industrial Development Fund (UNIDF). The second element of the project consists of two workshops, one in India and the other in Mexico, dealing with the industrial application of the information and data presented at the seminar.

The project is being planned and implemented by the International Institute for Cotton (IIC) in cooperation with UNIDO.

September 1984

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PROGRAMME

KNITGOODS SEMINAR ON

THE PRODUCTION OF HIGH QUALITY COTTON KNITGOODS

Organised by the International Institute for Cotton (IIC) and the
United Nations Industrial Development Organization (UNIDO)

April 2nd - 6th, 1984

SUNDAY, APRIL 1st

19.00	Informal reception at the Pinewood Hotel, Handforth

MONDAY, APRIL 2nd

09.30 - 10.00	Welcome and introductory remarks - UNIDO - Mr. A. Eraneva, Senior Industrial Development Officer - IIC - Mr. F. H. Burkitt, Director of Technical Research
10.00 - 11.00	Short summary statements by UNIDO invitees reviewing the status of the knitgoods industries in their respective countries
11.00 - 11.20	Coffee
11.20 - 12.30	THE MARKET FOR COTTON KNITGOODS by Roy Keeling, Director, IIC Marketing Division (UK) Discussion
12.30 - 14.00	Lunch
14.00 - 15.30	MARKET REQUIREMENTS IN CHAIN STORE RETAILING by B. Frank Moore, Quality Control Manager, British Home Stores, London Discussion
15.30 - 15.50	Tea
15.50 - 17.00	Short summary statements by UNIDO invitees (continued)

TUESDAY, APRIL 3rd

09.30 - 10.30	THE PRODUCTION OF COTTON KNITGOODS ACCORDING TO SPECIFICATION Production of Quality Knitgoods - A Framework for Action by Frank H. Burkitt, Director of Technical Research IIC Technical Research Division, Manchester Discussion

10.30 - 11.00	Coffee
11.00 - 12.30	Knitting to Specification by Jill C. Stevens, Development Officer/Knitting IIC Technical Research Division, Manchester
	Discussion
12.30 - 14.00	Lunch
14.00 - 14.45	Finishing to Specification
	Setting the Finishing Targets by Peter F. Greenwood, Finishing Manager IIC Technical Research Division, Manchester
14.45 - 15.30	Achieving the Targets in Practice by Robert D. Leah, Assistant Finishing Manager IIC Technical Research Division, Manchester
	Discussion
15.45 - 16.00	Tea
16.00 - 17.00	STARFISH - A PREDICTIVE APPROACH by S. Allan Heap, Assistant Director of Technical Research IIC Technical Research Division, Manchester
	Discussion

WEDNESDAY, APRIL 4th

Visit to the Circular Fabric Production Group of Meridian
Haydn Road, Nottingham

THURSDAY, APRIL 5th

09.30 - 10.30	THE DYEING AND FINISHING OF COTTON KNITGOODS - THE BALANCE BETWEEN QUALITY AND COST by G. Richardson, Technical Director, Courtaulds Fabric Division, UK
	Discussion
10.30 - 11.00	Coffee (and exhibition)
11.00 - 12.00	GARMENT MANUFACTURE
	Designing Well Fitting Garments by Bernt Johansson, Swedish Textile Research Institute (TEFO), Sweden

	Making-up of knitted fabrics by Ron Lloyd, Head of Sewing Advisory Service English Sewing Limited, Manchester
	Discussion
12.30 - 14.00	Lunch (and exhibition)
14.00 - 17.00	Visit to IIC offices and laboratories. Practical demonstrations of STARFISH on computer. Demonstration of test procedures as required.

FRIDAY, APRIL 6th

09.00 - 11.00	RECENT DEVELOPMENTS IN KNITGOODS MACHINERY AND PROCESSING
	- Terry Marns, Head of the UK Technical Services ICI Organics Division
	- J. T. Littleton, Marketing Director The Bentley Engineering Co. Limited
	- A. A. Moscaroli, Managing Director Rockwell-Rimoldi (Great Britain) Ltd
	- W.E.A. Shelton, Managing Director Alan Shelton Limited
	Discussion
11.00 - 11.30	Coffee
11.30 - 12.30	General discussion
12.30 - 14.30	Lunch (and exhibition)
14.30 - 15.30	CONCLUSIONS (Final plenary session)
15.30 - 16.00	Tea

EXHIBITION

April 5th and 6th only

There will be an exhibition of testing instruments designed for use in the knitting industry. These will include yarn tension meters, run-in meters, yarn friction testers, stitch length counters, regularity testers, instruments for measuring elastic properties of fabrics etc.

In addition, IIC will arrange a static display of diagrams and photographs to illustrate the various elements of its knitgoods programme.

UNIDO/IIC KNITGOODS SEMINAR

APRIL 2nd - 6th, 1984

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Mr. N. Alvarado
Knitting Manager, Texlamex, Naucalpan, Mexico

Mr. C. Stamboulidis
Technical Manager, Nornit Limited, Kano, Nigeria

Mr. S. H. Tahir
Director of Manufacturing, Schon Textiles Limited, Karachi, Pakistan

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Training Officer, International Institute for Cotton, Manchester

CONCLUSIONS AND RECOMMENDATIONS

Conclusions and Recommendations from the IIC/UNIDO Seminar on the "Production of High Quality Cotton Knitgoods" held in Manchester, April 2nd-6th, 1984.

1. The meeting recognised that the "STARFISH" programme has demonstrated its usefulness as a management tool for:
   - developing new cotton knitgoods, with substantial savings in time and costs,
   - examining product specifications,
   - identifying appropriate quality control measures,
   - guiding investment decisions,
   - contributing to a more efficient use of raw materials.

   It should be noted that at present the system is applicable to three basic constructions using combed yarns - single jersey, 1 x 1 rib and interlock - and the finishing routes* most commonly used for these constructions.

2. Customers are demanding better quality in terms of improved performance (e.g. lower shrinkage and better retention of shape and appearance) whilst maintaining current price levels. To satisfy this demand the application of quality control systems and appropriate test methods and close cooperation between spinner, knitter, finisher, garment maker and retailer are necessary in order to meet agreed specifications.

   It cannot be over-emphasized that this stringent monitoring of quality at all stages of processing is an essential pre-requisite for the application of the STARFISH system.

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* Winch and continuous bleaching, winch and jet dyeing, compressive shrinkage, tubular mercerising, open-width mercerising, cross-linking.

3. The STARFISH system, centrally developed by IIC, should be made available to cotton knitgoods producers wherever it is applicable. The meeting therefore recommended that

   - a series of satellites or sub-centres, coordinated and monitored by IIC, be established in locations where appropriate facilities and resources are available and where the cotton knitgoods industry warrants it;

   - the present STARFISH programme be expanded to include:

     (a) a wider range of constructions and finishing routes;

     (b) the use of carded ring spun, rotor spun and other types of yarns;

     (c) predictions for the sizing and performance of garments

   - additional resources be made available to facilitate this expansion.

THE MARKET FOR COTTON KNITGOODS

Mr. R. Keeling
International Institute for Cotton

World market for textile fibres is vast and growing. Intensely fought over by natural and man-made fibres and by individual suppliers of each type. 30 million tons of all types used in 1983, conservatively valued at over $60 billion.

Each inhabitant of this planet, on average, consumes 7 kilos per year. Market potential can be assessed by comparing effects of development on consumption e.g.

North America	20.0 Kg/pc
East Africa	1.4 Kg/pc
EEC	16.0 Kg/pc

Globally, cotton supplied 50% of total fibre demand in 1983, i.e. 15 million tons.

Cotton supply firmly secured as it is grown in 90 countries. Almost all classed as developing, including many of the least developed countries. Cotton's unrivalled importance as foreign currency earner ensures continuing commitment to its production - both as exportable agricultural commodity and as the raw material of national textile industries.

Compared with other agricultural commodities as foreign currency earner, cotton ranked 1st in 10 countries, 2nd in 14 and between 3rd and 6th in 14 more.

Raw cotton exports, from developing countries were valued at $3.3 billion in 1981, whilst exports of cotton textiles from those countries were valued at $6.4 billion.

Cotton therefore creates synergy between the rural and industrial economies and enhances the possibilities for adding value to the product within the producer country.

Cotton is a viable cash crop in the simplest rural economies, with very high yields being achieved on small-scale family plots.

It is also viable in the world's biggest and most sophisticated agricultural economies.

Realistic prices and sustained demand stimulate both large and small producers. IIC was created in 1967 as demand stimulating agency for world cotton.

Demand for all fibres has doubled since 1960; from 15.1 million tons to 29.8 million tons. Cotton, always the biggest single fibre type in the market, has seen its demand rise from 10 million tons to 15 million tons in that time.

Fundamental marketing appraisal must attempt to predict fibre consumption to the end of the century.

i. Most pessimistic assumption, based on declining birth rate and no increase in per capita consumption, world will need 41 million tons of fibre by 2000, of which, cotton will supply 45% i.e. 18.5 million tons.

ii. Reasonable assumption; cotton supplies 23 million tons of 46 million tons total.

iii. Optimistic assumption; cotton supplies 25 million tons of 55 million tons total.

(FAO's most optimistic assumption is for a cotton demand of 29 million tons).

Therefore, cotton demand should rise by at least 25% and, possibly, by 75%. Significant increases on an already substantial output. Reasonable to ask from where will extra tonnage come?

It is widely believed that cotton competes with food crops for land. As hunger is major concern and world population may be 50% greater in

2000, cotton must yield to food. This is not so because:

i. Present cotton production is grown on about 2% of the world's cultivated arable land.

ii. Land used for cotton growing is not usually suited to food crops.

iii. There is no food shortage in the world, there is a shortage of money to buy and ship it.

Cotton is a cash-crop, it earns money and breaks vicious circle of subsistence farming.

iv. Most important factor:
improvement in yields; up 56% in 20 years, from 299 kilos/hectare in 1960 to 466 kilos/hectare in 1980.

Even greater improvements possible:

World average yield	464 kg/h
Highest yield (Israel)	1441 kg/h
Lowest yield (Uganda)	42 kg/h
(USA)	464 kg/h

If lowest yields can be improved to current world average by the end of the century, then much of extra demand will automatically be met with no significant expansion of hectarage.

Cotton production has, within acceptable margins, kept pace with increasing demand, at reasonable prices, mainly thanks to possibility of annual adjustments to the supply when planting.

Man-made fibre production capacity, on the other hand, has expanded at a far greater rate than the markets could absorb. Multi billion investments, tied to long amortization time scales, have seriously damaged the parent chemical companies and dislocated future investments in this area.

Clothing and textile manufacturing capacity has expanded globally at an equally over-ambitious rate. It is estimated that clothing manufacturing capacity is currently about 40% ahead of offtake.

A buyer's market is firmly established and the problems shift from production to marketing.

Sluggish markets, over capacity and excessive use of price as the only valid market stimulant suggests that the general migration of textile and clothing manufacture, from high cost developed locations to lower cost developing countries will continue.

Migration moves producers long distances from their customers and consumers and across language and cultural frontiers. Creates immense problems for producer to maintain intimate involvement in final market to evaluate its pitfalls and opportunities. Strengthens position of intermediaries.

Consider scale of this migration:

> Since 1960, whilst global mill consumption of cotton increased by 50%, the amount processed into textiles in the developed world has declined from 42% to 24%, whilst that processed in the developing world has risen from 24% to 36% and that in socialist countries from 34% to 40%.

But the developed countries remain the prime consumers of this re-sited production.

Main focus today on Western Europe, here listed as 15 countries of which 10 are members of the EEC and 2 are negotiating for membership.

These countries account for:

8% of world's population
29% of the world's GDP
350% of the world's average per capita GDP

Their importance, in terms of world trade is illustrated by:

i. As a destination for world's exports of all products, 40% arrive in Western Europe, a trade which has grown in value by 1,000% since 1965.

ii. As a destination for world's exports of fibres, yarns, fabrics and clothing (an already mature trade in 1965), 62% arrive in Western Europe, valued at $70.8 billion and increased by 870% in value since 1965.

The net effects on cotton consumption in Western Europe since 1960 are as follows:

Cotton spindleage down by over 50%
Population up by 14%
Per capita cotton consumption up by 7%
Total cotton consumption up by 22%

Cotton consumption in Western Europe falls into three broad categories:

Apparel	45%
Household	38%
Industrial	17%

Focussing on apparel and taking as an example the United Kingdom, whose population is comparable to France, Germany or Italy, an apparel market of about 206,000 tons of all fibres is indicated which is disposed as follows:

Menswear	42%
Womenswear	43%
Boyswear	9%
Girlswear	6%

Cotton's share of these markets, by weight, is:

Menswear	42%
Womenswear	29%
Boyswear	39%
Girlswear	50%

Liberal governmental import policies coupled with extreme price sensitivity in bulk areas of these markets has led to significant market penetration by overseas suppliers.

> Example:
> The UK's balance of trade in textiles in 1982 was minus $976 million and minus $970 million in clothing; a combined deficit of $1,946 million or 94% of the UK's trading deficit of $2,060 million that year.

Examination of import data shows generally higher penetration of menswear than womenswear. There are a number of possible reasons for this.

i. Considerable proportion of menswear is tailored, therefore, more expensive than assembly of womenswear. Domestic costs rose to levels market could not/would not sustain.

ii. Collapse of few dominant menswear producers left market open to overseas suppliers.

iii. Menswear generally less fashion sensitive than womenswear and therefore easier to obtain from overseas.

iv. Manufacture of womenswear less capital intensive, more suited to small entrepreneurial manufacturer capable of meeting highly varied short-run demand.

Of these reasons, the need to quickly interpret fashion and to exploit it has protected the position of the national womenswear manufacturer.

Fashion, i.e. colour, style and design affects whole womenswear markets and, increasingly, the menswear markets vertically, by price and horizontally, by age. Common factor is the style/value equation.

Fashion is no longer a whimsical option, it is a structured and reasonably predictable yet creative marketing tool. It affects the whole market, i.e. manufacturing, distribution, retailing and the final consumer. It is supported by heavy investment and by widely available fashion media. It is interactive, not autocratic and both producers and merchandisers should be responsive to its constantly changing emphasis.

Above all, fashion is a tool with which to maximise the apparent value of the current product and to accelerate the obsolescence of previous merchandise. Therefore, whilst absolute and relative quality are still fundamental tools of competition (with consumers closely protected by legislation) style and colour demand equal attention from all manufacturers.

It may be useful to note the analytical and forecasting facilities in these areas, provided to its members by IIC.

i. Detailed colour forecasts 2 years in advance of the retailing season, mainly to guide fabric producers in seasonal fabric range building.

ii. The colour forecast coupled to styling predictions, illustrated with sample fabric swatches, mainly for garment manufacturers and retail/own brand/buyer/selectors, one year ahead of the retailing season.

iii. Intermediate updates throughout each seasonal two year cycle.

Fashion is not only cyclical in seasonal terms but also in terms of longer pervasive trends in dressing which attract different sectors of society in different ways for differing lengths of time.

> Example:
> As developed societies move away from their manual labour bases, losing virile man/dependent woman relationship, work clothing becomes nostalgic designer theme permeating formal and informal clothing.

The questions national and overseas manufacturers have to ask are:

How long will this trend persist?
How far will it penetrate the market in terms of volume?
How will I know that it is declining?
When shall I join the trend?
When should I leave it?
How will I recognise the one that is replacing it?

It is clear that the overseas producer has far more difficulty in answering these vital questions than the national producer. He rarely meets, or gets involved with consumers who answer all questions by the way they spend their dollars. Clearly, he will have to rely on intermediaries to act on his behalf; at possibly considerable cost in terms of f.o.b. values of his exports.

Targeting a product on the right consumer demands considerable knowledge of the distribution and retailing systems through which sales will be achieved. Although basically price segregated, they are complex, with many overlapping alternatives, apparently serving the same public. Broadly speaking, the retail systems of Europe consist of:

i. Independent stores

Although widespread (e.g. 80% of all UK clothing outlets), usually small in unit size, turnover and stock capacity. Take about 30% of total sales in UK.

ii. Multiple outlet stores

Small in number, considerable turnover (e.g. 1% of businesses take 50% of total turnover in UK). Centralised management in charge of operations and procurement of merchandise. Great concentration of buying power; great responsibility to buy well.

iii. Mail order

Selling, on credit, from catalogues of merchandise, circulated around rural and urban localities. (About 10% of clothing/textile sales in UK). Sometimes divisions of conventional retailers.

iv. Others

Hypermarkets, supermarkets, discount traders, food retailers, market stalls, etc.

Except for market stalls, trading mainly in remaindered textile goods, others centralised as multiple outlet organisations.

Access to these sales channels gained in a variety of ways, e.g. via:

Importers, agents, direct sales, trade fairs, etc. etc.

In general, multiple traders have tended to gain sales at the expense of independents for obvious reasons such as:

Variety of merchandise under one roof, good price/value ratio achieved through greater buying power, suppliers, owners and customers gain benefits of economics of scale, attract high quality staff and management, create attractive shopping environments etc. etc.

Previous advantages of smaller units more accurate targeting on specific customer types is being taken over by very precisely positioned multiples, aiming to cater for a narrow age span at a certain income/social level.

Such close analysis of the structure of the retail system and ensuing understanding of how each sector works and differs from another, is key to product development in terms of quality, style, volume and price. In many cases this guidance is provided by the buyer if a 'cut make and trim' contract is entered into. However, clearly a price has to be paid for diminished responsibility in terms of lower f.o.b. prices to the exporter. It therefore should be his long-term ambition to come to market with a fully developed and accurately targeted product to maximise his returns.

Looking specifically at knitwear and cotton's position in these markets, two broad divisions occur:

i. Fine gauge knits, usually from circular machines
ii. Heavier gauge knits from flat bed machines

Cotton has been extensively used in the first product area and is now beginning to be significant in the second.

The first group consists of products such as undervests, underpants, etc. T-shirts and sweater shirts, supplemented by newer products for active sports and exercising for adults and children.

Most of these products are well established, almost 'commodity' items of clothing as the UK sales pattern illustrates:

	1975	Million Units 1980
Total	349	356 +2%
Cotton	121	185 +53%
Cotton tonnage	8,250	12,600

Individual product performance, indexed to 100 in 1975 is as follows:

	1975	1980
All T-shirts	100	165
Cotton T-shirts	100	207
All sweater shirts	100	118
Cotton sweater shirts	100	228
All undervests	100	83
Cotton undervests	100	103
All underpants	100	100
Cotton underpants	100	157

Cotton products have out-performed the all product index, even in no-growth and slow-growth product areas.

Jerseys, pullovers, cardigans and similar heavier knits, form the second merchandise group. It is a very heavy consumer of yarn and has tended to gain in importance as a more leisurely style of dressing becomes the norm.

Historically, these markets have been considered the preserves of wool or wool substitutes, such as acrylic fibres. Within the last five years cotton has not only appeared in these products, but has made rapid progress towards a significant market share.

Originally, it came in on a fashion presentation, with high aesthetic content but sometimes less than satisfactory performance. It is now being taken up by sizeable producers as acceptable consumer characteristics are being imposed.

A few years ago, it would not have been possible, statistically, to identify cotton in these products; it would have been lost in 'other fibres'. In 1982, Eurostat, the EEC import/export data, identified 20,405 tons of cotton imports within a total of 101,000tons of all fibres from the world to the EEC in these products.

Much of the remainder of your programme will be devoted to the vital subject of producing goods efficiently and consistently to specified quality standards.

I hope that this short paper has reminded you that the market place will be the final arbiter of your success. The market place can become more transparent and more supportive if product development and market development go forward hand in hand.

IMPORTS OF KNITWEAR, FROM WORLD TO EEC, 1982

	Cotton	%	Others	Total
Babies T-shirts	637	(88)	83	720
Babies vests	39	(42)	53	92
T-shirts	23747	(87)	3448	27195
Vests	297	(29)	730	1027
Mens and boys shirts	6289	(57)	4794	11073
Mens and boys pyjamas	5546	(82)	1230	6776
Mens and boys underpants	9001	(96)	350	9351
Womens and girls nightdresses	2710	(64)	1520	4230
Womens and girls underpants	7817	(81)	1854	9671
Womens and girls pyjamas	3754	(82)	815	4569
Tracksuits	3914	(39)	6102	10016
Womens and girls blouses	1652	(31)	3606	5258
Mens and boys jerseys, pullovers, cardigans, etc	11047	(25)	33084	44131
Womens and girls jerseys pullovers, cardigans, etc	9358	(16)	47514	56872
Womens and girls dresses	2064	(15)	12073	14137
Womens and girls skirts	399	(19)	1681	2080
Coats and jackets	282	(16)	1445	1727
	88553	(42)	120382	208925

DISCUSSION

MR. R. KEELING'S PAPER

Speculation about the rate at which textile production processes were migrating from high wage to lower wage areas was the major discussion topic. Was the capital intensity of the industry increasing to the stage where developing countries could not afford it? Technological development seemed to be such that it affected not only machine productivity but also product quality - the first being related to fabric cost and the other to its marketability. If the trend was becoming steeper then both would work against the interests of the developing countries.

It was pointed out that in the UK, for example, wage costs had been escalating for many years; also the government had conditioned investment by its taxation structures more towards investment in machinery and plant than towards investment in labour. Thus two elements had been working together to make it desirable to minimise labour costs in favour of high technology and high capital cost equipment. One might expect the drift to continue. In the depths of the recent recession - in 1981 to 1982 - cotton spinning capacity was halved, in two years. Once these spindles had been taken out users would have to rely more on imported yarns. Yarn users were diminishing as well - weaving machinery had been reduced to something like 20,000 looms.

The answer for a questioner on the future prospects for OE-spun yarn in cotton knitting was that although OE-spinning was a system which could not be ignored on the grounds of productivity and lower labour investment, it had limitations at present in medium and fine counts - just those areas of most concern to the knitter. Growth could be expected to be very slow there but for coarser counts the OE system must come along as and when replacement of obsolete spinning machinery was justified.

MARKET REQUIREMENTS IN CHAIN STORE RETAILING

B. F. Moore
British Home Stores PLC

In terms of modern Chain Store Retailing there are four main marketing aims to be fulfilled:-

1. Know your customer.
2. Provide your customer with the quality of merchandise they require at the correct price.
3. Provide your customer with a quality of environment in which shopping is enjoyable and not a chore.
4. Ensure the merchandise being sold is well presented.

Chain Store Retailing in the UK over the past 30 years has dramatically changed. The 1960s was the age of the manufacturer when demand for goods was greater than supply sources. This was the period during which the manufacturer achieved success.

The 1970s saw the large growth of other supply sources and the slower growth in consumer demand. It was the period when the retailer took advantage of their negotiating power and did extremely well in terms of growth and profitability.

The 1980s is the age of the consumer - they are more discerning in their selection of goods from the wide choice of retailers and suppliers.

This change in the balance of power to the consumer has necessitated a change in the focus of buying from simply making a product available to 'target customer merchandising'. In other words 'what does the customer want first and can we provide it' rather than 'this is what we have, let's try it on the customer'.

In order to satisfy ones customer the first question to be answered is 'who is the customer' - the man, woman or child to whom we are selling merchandise.

Customers are changing and the factors to take into consideration are:-

Age structure
Household size
Work and leisure time
Unemployment
Real incomes
Womens emancipation
Education
Health and fitness

The more we can understand about the customer the better equipped we are to meet their needs.

Let us take one of the factors mentioned - age structure - and examine how this is changing (figures in millions).

Age group	1981	1991	
Under 15	11.1	11.8	+
15 - 24	9.2	8.2	-
25 - 44	15.6	16.5	+
45 - 65	12.1	12.1	0
65 and over	8.4	8.5	0

Within the under 15 age group the under 10's are going to grow and the 10-15 age group decline - not because we are having more children per family but because there are more women moving into the child rearing age group of 24-40.

Therefore one can clearly establish a major market share being in the 25-45 year old category and the under 15s with emphasis on infantswear.

Let us look at earning power of the household. One third of the total population of households account for the 13% of total non-food spending. These were the households earning less than £5,000 per year in 1981.

At the opposite end of the scale the 38% of the households earning more than £9,000 per year account for 60% of non-food spending.

From these two sets of figures alone it is not difficult to suggest that a chain store retailer should aim his market at the under 15s and the 25-45 age groups of households earning over £9,000 per year.

As you will appreciate from these few facts alone clear identity of customer profile is of paramount importance in establishing where our retail market exists.

The customer we have just defined, the under 15 and 24-45 year old adult is roughly the C1 - C2 group in socio-economic scale and is the one who demands merchandise offering value and quality.

This does not mean lowest prices but the right merchandise at the right price.

Quality in this context can be defined both subjectively and objectively.

Subjective assessment relates to merchandise style, design, colour, aesthetics and comfort.

Objective quality can be defined as fitness for purpose with good size and fit.

One can claim to have achieved good quality if you can satisfy the customer in these criteria whilst offering the merchandise at a competitive, acceptable price.

Subjective quality parameters are well nigh impossible to define and here we are in the hands of buyers correctly reading fashion and colour forecasts.

Objective quality in terms of fitness for purpose has over the years been clearly defined through International and National Standards supported by Performance Standards and Test Methods issued by the major retail companies.

One of the major problems encountered after going to extensive lengths to define Objective Quality Standards is that of consistency throughout bulk production. Finished garment quality as seen today demands an overall improvement in this area.

The management of factories often do not appear to be aware of the standard of products leaving their premises. Manufacturers believe they have good quality control procedures for controlling the standards of product they are producing but these systems often do not reflect the standard of the finished item.

Good manufacturers using the latest equipment and most sophisticated quality control techniques during production can and do let themselves down by not ensuring the standard of product leaving their factories is commensurate with the people they are selling to. This is an important factor and one which you should all take account of in your own production units.

Having established the customer profile and having produced and provided the quality of product they demand we must now turn our attention to the store in which the goods are to be sold.

In modern store retailing two important factors to consider are:-

1. Quality of merchandise presentation.
2. Quality of the store.

In terms of presentation it is essential that merchandise looks and feels appealing to the customer. The best most well constructed garment if pressed incorrectly or badly packaged will not sell.

Presentation is what the customer first sees when viewing merchandise and therefore it must reflect the character and good quality of the article. Small items like quality and consistency of labels and signs across and within ranges must be uniform.

The quality of presentation must reflect the quality of the merchandise.

The customer having selected an item they wish to purchase expect and rightly so should receive good service. The sales assistant should be well presented and make the customer feel relaxed whilst making a purchase.

The final point on Quality in modern retailing which must not be overlooked is the Quality of the store itself.

This is what first attracts a customer in to examine merchandise prior to making a purchase. A modern store should be inviting, be attractive in design and let the customer 'feel at home'.

Within British Home Stores we have during the past few months made what we consider to be one of the most major changes seen in chain store retailing for many years.

In July 1982 we made a courageous decision to create a store with a totally new image. In November 1982 the first of this new generation of stores opened in Harlow, Essex.

The first noticeable point about these stores is that they contain no traditional type counters. It is a store constructed round a central walkway which effectively creates defined shops within a shop.

The area shops created contain the various departments - menswear - ladieswear - childrenswear - household goods - lighting etc.

The second major feature is the display of merchandise which in chain store terms is revolutionary. Knitwear for example is displayed hanging rather than in flat packs on a store counter. This allows the customer greater freedom to see and feel the merchandise prior to making a purchase.

Greater use is made in each section of creating garment displays which by use of clever lighting techniques produces an attractive appealing range. Gone too are the traditional large price tickets and signs. In their place are pleasant graphic designs and clear unambiguous price displays.

The image we have created is that of a modern Quality store in which the customer can feel at home and enjoy her shopping.

We at British Home Stores believe we have created a new generation of chain stores within the UK on which to build our success for the future.

Chain store marketing is to do with people. A successful company must be able to adapt itself to the changing social and buying habits of its customers. If the environment changes, the company must change with it or it will gradually die.

This paper provides an insight into a few of the important market requirements that must be seriously considered to achieve success in a modern chain store retail operation.

DISCUSSION

MR. B. F. MOORE'S PAPER

Tolerance figures for knitted garments of ±2½% in the case of wales and courses and ±5% for weight had been mentioned during a video presentation. A questioner wanted to know whether these figures were standard for Britain generally or just for British Home Stores. The answer was that they were especially relevant to British Home Stores but that they also reflected what the industry within the UK was working towards.

Colour fastness also was totally important. The reason it had not been mentioned earlier was that a knit-and-sew operation was being described in the video; colour fastness standards would already have been checked out in the fabric before garment production began. BHS in fact gave out colour fastness standards to all their manufacturers which in some cases, were modifications of both British and International Standards.

One modification which the speaker had personally introduced was the use of a detergent wash for colour fastness testing because that was what their customers were using to do their washing. They were not using soap or soda. Only this year was it virtually becoming an international standard, so when the ISO TC 38 meeting convened in June 1984 to ratify the detergent colour fastness test it will have taken 15 years to achieve a realistic standard.

Stability testing was another point mentioned. Over 30% of all households in the UK were reported to have access to tumble dryers so it was now necessary to start looking at performance standards based on the use of this method of drying.

A suggestion that shrinkage standards in future might improve more and more to the point of zero shrinkage, even for tumble drying, was not entirely acceptable to the speaker. When one was talking about knitgoods there was always a degree of what one could call "recoverable shrinkage" when a garment was put on. What was needed was a garment which fitted when it was bought and still fitted after washing and tumble drying rather than having to oversize the garment initially to accommodate shrinkage which would take place later. There would always be a measure of shrinkage which was recoverable so if one could get down to 5% on tumble drying that probably would be acceptable to a consumer.

On quality it was emphasized that attention should be given to the trimmings as well as the basic fabric. A garment was only as good as its poorest trimming; a poor quality zip fastener, poor quality buttons or poor quality sewing thread created a poor quality garment.

Asked whether the different weights of the same garment were acceptable for different colours, the speaker said the answer was 'no'. If fabric was going into a T-shirt which was to be sold in six colours the textile technologist in the factory would be expected to have it worked out so that the garments on the counter were uniform in weight. It was becoming very important, particularly with coordinated merchandise where there might be about five manufacturers making the same garment, that the colours matched exactly and the weight and feel of the garment was consistent as well.

The retailer's psychological trick of pricing everything at 99p was queried but delegates were assured that price points were just as important as ever. The difference was that now prices were being rounded up in terms of a 10p step so that a garment would be priced at £4.90 rather than £4.99. The psychological barrier was still very important in the UK.

Ideally one might suppose that the large retailer would send staff overseas to make quality inspections at suppliers' factories but when one was buying in world markets the important thing was to try to educate the manufacturers, to make sure they were aware of the standards they should be providing. The speaker did not believe it was the retailer's job to send technologists around the world inspecting and checking products. They might be sent out initially to make sure an understanding had been reached or, alternatively, the manufacturer might be invited to spend some time with them in the UK.

To a questioner who asked why BHS had changed its policy in recent years to buying more merchandise in the UK than overseas, the speaker said it had a lot to do with quality and with consistency of quality. Much merchandise was still bought abroad but the UK customer was now wanting higher quality standards and obviously it was far easier to control quality if goods were produced on one's own doorstep. There was also an increased demand for fashion merchandise and if this was brought in from abroad there was not always sufficient time to get it through the pipeline and into the store during its selling period. One tended therefore to go abroad for very basic merchandise where only minor fashion changes would occur over a long timespan.

It was made clear to the seminar, however, that when goods were bought abroad their quality had to match that obtained from the UK and that to sell in the UK, and particularly to the major retailers, suppliers must be very clearly aware of the requirements of those retailers and ensure those requirements were satisfied, otherwise there would be rejections. It was probable that the UK, Germany, Scandinavia and Japan demanded the highest quality standards in the world at present.

PRODUCTION OF QUALITY KNITGOODS

- A FRAMEWORK FOR ACTION -

Frank H. Burkitt
International Institute for Cotton

THE IMPORTANCE OF QUALITY

The title of this Seminar contains the words "high quality" and it is worth spending a few minutes to explore the reasons why cotton knitgoods manufacturers need to upgrade the quality of their products and why we in IIC should help them to do so.

Traditionally, knitted cotton fabrics have been used for underwear where appearance and performance levels can be relatively low. Now, however, there is a rapidly growing interest in knitted cotton for outerwear where standards of fit, appearance and performance must be much higher because the garments are visible. The range of fabric constructions and colour decoration is also much wider in outerwear garments.

Domestic laundering practices are changing and more and more people are using tumble dryers in their homes or in launderettes. The tumble dryer is, as we will see later, an extremely efficient machine for exposing the shrinkage potential of any garment and thus, with current products, customers are finding even higher shrinkages than they had experienced with line or flat drying.

We also see the growing importance in several countries of large chain stores and their policy of refunding to the consumer the purchase price of an unsatisfactory product. Such stores need to have more than one source for each item and hence they demand not only quality and consistency from each supplier but also consistency between suppliers.

Finally, we believe that consumers generally are looking for a higher level of quality in products where fashion considerations are not of dominant importance and that they are prepared to pay for that quality. If they cannot buy quality cotton products, there will be an inclination to purchase blended or all synthetic products.

Thus we believe that upgrading of the quality of cotton knitgoods is an objective on which all sectors of the processing industry, the retail stores, the consumers and the cotton growing countries can all agree.

But how can this high quality be achieved?

The papers to be presented today by the staff of IIC are devoted to different aspects of the production of cotton knitgoods according to specification. The words "to specification" have been deliberately included in the title to emphasize that high quality knitgoods cannot be produced consistently unless everyone involved - knitter, finisher, garment maker, and retailer - cooperates in a clearly defined plan - a specification. This may be laid down by a retail store, a garment maker or by a knitter. How the specification arises is not important but it must be self-consistent and realistic so that it does not make impossible demands on the processor.

Cooperation between all the parties is absolutely essential. All too often, for example, a finisher is faced with a task of trying to meet a specification using inappropriate grey fabric he has received from a knitter. However, for such cooperation to be effective, quantitative information must be available to relate the properties and dimensions of the finished fabric to the knitting parameters and the finishing route.

The provision of such data and associated know-how was the objective of the IIC programme.

It is also important that a high level of quality is not only achieved but is maintained day after day, week after week. Many store buyers in Europe, Japan and the USA place large orders for a single item and expect - indeed demand - that the variability of quality shall be as small as possible. Every sub-standard garment means a dissatisfied customer and a financial loss both to the store and to the supplier. So at every stage down the processing line, suitable quality control procedures must be adopted to minimise the variability of the final product. The IIC programmes also make a useful contribution to this objective.

SHRINKAGE

Everyone knows that shrinkage and loss of shape is the main problem in cotton knitgoods but shrinkage values measured on a single sample can vary widely. In a recent trial we measured the shrinkage values of a range of fabrics by two different methods. Method A involved one wash followed by flat drying and returned values in the range 1 - 5%. Method B involved five washes followed by tumble drying and gave values in the range 12 - 19%.

It is useful to examine why shrinkage occurs and why such widely differing values can be observed. This analysis will lead us to appropriate and reliable test methods and also to the concept of a "REFERENCE" state which will help us to develop fabrics with specific properties.

During staple spinning, fibres are twisted together to form yarns and during the knitting operation, these yarns are bent into loops. The fabric is then pulled from the needles by take-up rollers. It is therefore not surprising that fabric taken from a knitting machine is in an unstable state and will try to relieve these internal stresses and move to a more stable condition. Processes which will relieve stress include simple wetting and drying, mechanical agitation or, best of all, a combination process such as tumble drying.

Fabric relaxation is always accompanied by dimensional changes as the knitted loops re-arrange into a more stable configuration. These changes can be quite large and may be 15 - 20% or more in length and/or width. Usually the fabric shrinks in both directions, but occasionally, the width may expand. Fabric thickness usually increases.

During the commercial production of cotton knitgoods, the scouring, bleaching, dyeing and drying processes produce some degree of relaxation - but some operations can also introduce new stresses into the fabrics. Thus a commercially finished fabric is practically never in a condition where all stresses have been relieved and therefore it will always have some residual shrinkage. The magnitude of that shrinkage clearly depends upon the processing history of the fabric.

TEST METHODS

It is obvious from the above that different washing procedures used to measure shrinkage will produce different degrees of relaxation and hence different shrinkage values. It is therefore necessary to use standard test methods which:

- allow for virtually all the potential shrinkage in the fabric to occur and be measured
- give reproducible results
- are not too expensive in time, labour and materials
- relate reasonably well to consumer washing and wearing practices.

It is important to recognise that test methods which are suitable for research work may be different from those which would be used, for example, by retail store groups to assess end-use performance of a garment, or those needed for quality control purposes in a mill. In all these cases, the criteria listed above will apply but their relative importance will be different for each application. Thus the research man will concentrate on the first two criteria whereas the testing laboratory of a retail store group will give greater emphasis to the last two.

We have examined a range of possible test methods. Initially, we concentrated on methods which were appropriate to our research programme but later we have looked at shorter test procedures which would be more acceptable to the industry and store groups. The relationship - if any between the shrinkage values given by the two sets of test methods has evolved naturally from these studies.

In order to meet our first criterion - to allow virtually all the potential shrinkage to develop - it is essential to have some form of washing operation followed by tumble drying. It is also necessary to repeat these wash/tumble dry cycles as can be seen from Figure I which shows the different patterns of shrinkage which can occur on repeated cycles.

For our research work, we decided to use five cycles, the first being a wash/tumble dry cycle followed by four rinse/tumble dry cycles. Full details are given on the attached sheet (Figure II).

Fabrics which have been relaxed in this way are described as being in their REFERENCE STATE and much of the data which will be presented by IIC staff during this Seminar is derived from measurements on samples in this condition.

Industrial and retail laboratories naturally favour a shorter test and are beginning to adopt a single wash/tumble dry procedure. Figure I and other results show that a one cycle test usually underestimates total length shrinkage, but gives a reasonable approximation to total width shrinkage. Occasionally total width shrinkage may be over-estimated by a one cycle test.

We have also found that it is necessary to test several samples from each fabric in order to achieve satisfactory reproducibility. For research purposes, five samples are used and this normally gives results which are secure to ± 2 percentage points. For industrial purposes a minimum of two, and preferably three, samples should be tested.

For countries where many consumers use tumble driers, the above test procedures are clearly appropriate. However, there are many parts of the world where tumble drying is rarely, if ever, practiced. In such situations tests based on line or flat drying may be adopted but care should be taken to ensure that the chosen test procedures give reproducible results and that sufficient samples of each fabric are taken to ensure a reliable average. Generally, the results from line or flat drying are less reproducible than those from tumble drying because of operator effects.

THE REFERENCE STATE

As mentioned earlier, a knitted cotton fabric which has undergone five wash/tumble dry cycles is said to be in its REFERENCE STATE, since this is the state in which shrinkage, constructional and property measurements are made. The dimensions and structure of a fabric in its REFERENCE

STATE depend upon the original knitted construction and the way in which the fabric has been finished

For example, changes in yarn count and stitch length will produce changes in the dimensions of the fabric in its REFERENCE STATE and each different finishing process will exert its own unique influence upon yarn diameter, stitch length and loop shape and therefore upon fabric dimensions. For some finishing routes, these influences will be small but in the case of mercerising and easy-care finishing, the changes can be so large that the starting fabric has to be redesigned in order to preserve the desired levels of weight, width and shrinkage.

As a result of our very extensive work on a wide range of knitted constructions and finishing routes, we are now able to calculate the REFERENCE STATE characteristics of many fabrics. This information is very valuable to a finisher since, from the REFERENCE dimensions he is able to calculate the finished dimensions which correspond to the required shrinkage laid down in the specification. For example, if the REFERENCE width of a fabric is 60 cms, and the shrinkage required is, say, 7%, the finished width must be about 65 cms.

It is important to recognise that there are, in theory, an infinite number of reference states each of which is related to a particular washing/drying test procedure.

We in IIC chose the REFERENCE STATE associated with five wash/tumble dry cycles as the most suitable for our purposes and virtually all of the data to be presented by IIC speakers is based on this concept.

However, as you will hear later, a finisher and a garment maker can agree to use a test method different from ours. This is perfectly satisfactory but it does mean that our data cannot be used without some corrections being applied.

PRACTICAL ADVICE

The information given by the IIC speakers is all derived from experimental work carried out over several years under full-scale processing conditions.

To date, we have produced and measured the properties of about 1500 finished fabrics. We have examined 1 x 1 rib, interlock and single jersey constructions made from combed yarns in the count range 1/16's Ne to 2/80's Ne. The knitting and finishing of all these fabrics was carried out on commercial equipment under very careful control by IIC staff. Typically, the length of each finished sample was 60 metres.

All of the testing was carried out in our own laboratory and great care was taken to ensure an adequate number of samples was tested to give a reliable average.

The whole operation has involved extensive cooperation with mills in the UK, Germany and Italy and we are greatly indebted to the willingness of these organisations to allow our staff into their production plants.

The results from our programmes are already being used by a number of knitgoods processors and store groups and we have plans for wider dissemination through national organisations in a number of countries.

We recognise the limitations of our work; we have, for example, used only combed ring spun yarns made from a few growths of cotton. But the response we have received from industrial users has encouraged us to present our findings to a wider international audience.

CONCLUSIONS

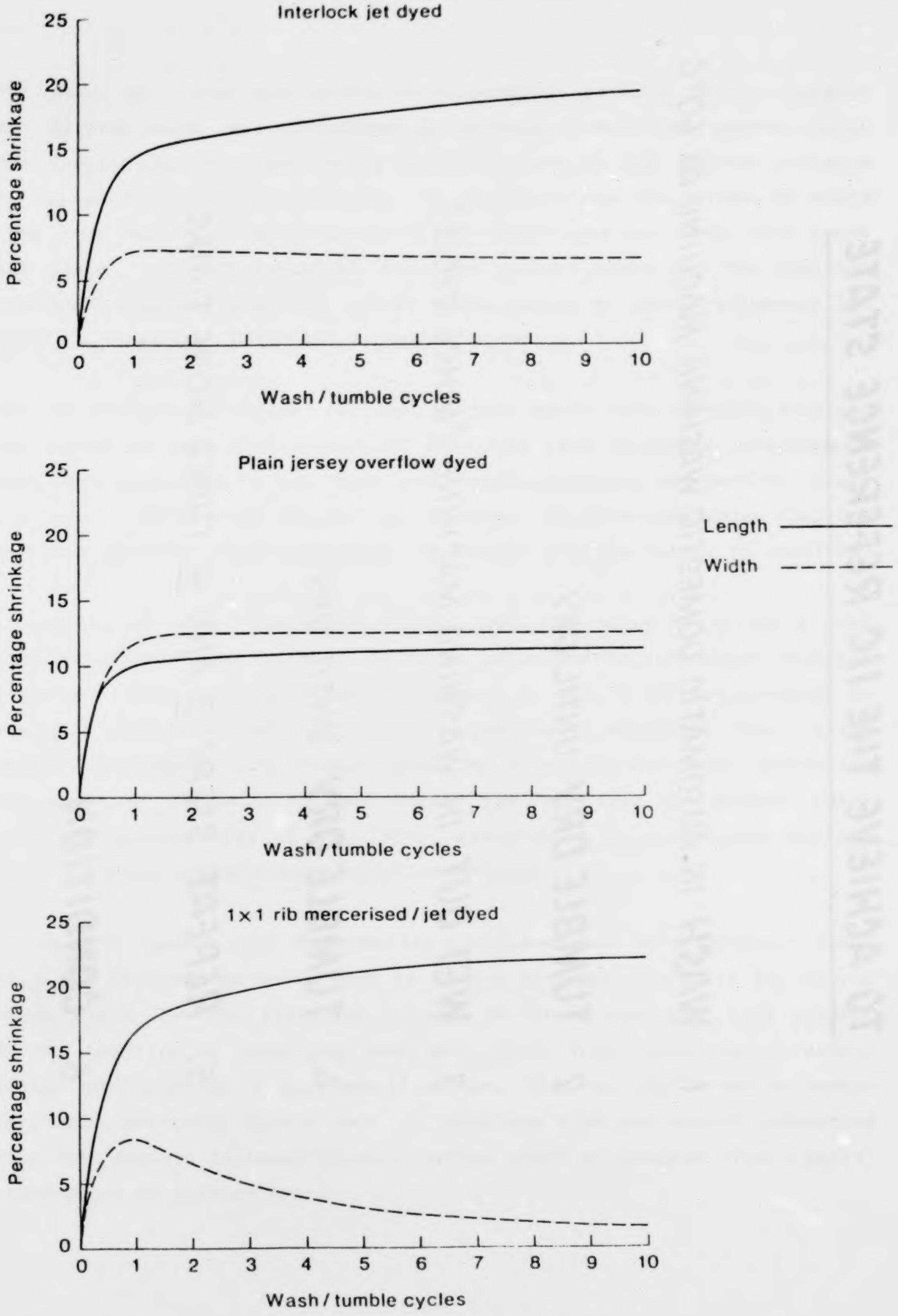
The purpose of this paper is to give a broad overview of the thinking behind the IIC knitgoods programmes and to pick out the key factors which we feel are fundamental to the production of high quality knitgoods. These are:

i) the need for closer cooperation between yarn supplier, knitter, finisher and garment maker
ii) the need for quality control at all stages
iii) the importance of using suitable test procedures for measuring shrinkage
iv) the concept of a REFERENCE STATE as a basis for shrinkage measurements and for calculating finished dimensions.

The remaining papers will explain how these basic ideas, together with our extensive data and know-how, can be exploited to produce quality knitted cotton products.

Figure 1

SHRINKAGE BEHAVIOUR PATTERNS



Interlock jet dyed

Plain jersey overflow dyed

1×1 rib mercerised / jet dyed

Figure 2

TO ACHIEVE THE IIC REFERENCE STATE

1. **WASH** IN AUTOMATIC DOMESTIC WASHING MACHINE AT 60°C
2. **TUMBLE DRY** UNTIL DRY
3. **WET OUT** IN WASHING MACHINE (RINSE CYCLE)
4. **TUMBLE DRY** UNTIL DRY
5. **REPEAT** STEPS 3 AND 4 THREE MORE TIMES
6. **CONDITION**

DISCUSSION

MR. F. H. BURKITT'S PAPER

The need for close and effective cooperation between fabric finisher and garment maker was underlined at question time. The garment maker was looking for a fixed fabric width because he had certain patterns to lay on the fabric for cutting. If the fabric was too narrow, he would have some very serious problems; if the fabric was too wide, then there was waste. It was essential that the garment maker and the finisher discussed together what the fabric width should be making allowance for a little relaxation after the finishing operation.

Various questioners pointed out that garment makers were becoming stronger and tended to have more commercial authority than finishers; furthermore they were organised to cut their patterns by computer and were no longer flexible in their requirements. On the other hand the commission finisher was in a terrible position; he had no control over the fabric he received.

Commenting on this, the speaker said that the value of having a tool such as STARFISH was that it could be consulted by a finisher whenever a garment maker came along with a demand to see if it was possible to supply a particular fabric width and a particular shrinkage from a given knitted structure. An answer could be given without even processing one piece of fabric. If that answer was 'no' then the garment maker could be advised that if the fabric was knitted in a different way the required width and shrinkage could be achieved.

The speaker agreed that the commission finisher was in a difficult position and believed he would need to take a stronger line with the people whose fabric he was finishing because he could certainly find himself in the position of receiving some grey cloth which there was no possibility of finishing to meet specification. That was why it was so important that everybody should talk to everybody else and should understand that only certain finished characteristics could be obtained from a particular piece of knitted fabric.

Asked whether the finisher could do anything at all with a fabric to help him meet a fixed width specification and a fixed width shrinkage specification by varying the processing route, another IIC speaker did suggest that marginal adjustments could be made. It has been found, for instance, that jet dyeing tended to produce a wider fabric than winch dyeing. If problems were encountered with width shrinkage and it so happened that the fabric was being winch dyed then one could try jet dyeing where it should be found that the shrinkage was a little lower and possibly then acceptable. However, it was emphasized that there was in fact only one general answer to that question; namely that the finisher must make sure one way or another that the knitter was supplying a fabric which had been constructed appropriately for the end-use.

A questioner who used mercerised yarns to knit his fabrics and then had the fabric mercerised, commented that if one used unmercerised yarns, the subsequent fabric mercerisation resulted in yarn shrinkages of as much as 8%, which really altered fabric handle. He was told that one of the examples often used to explain the use of STARFISH concerned a man who had been producing a winch-dyed fabric for several years to his customer's complete satisfaction. One day he sent some of his regular fabric to be mercerised. It came back beautifully lustrous but very much narrower and very much heavier than the original fabric. He knew his customer would not want that fabric so the knitter had to reconstruct it to allow for the yarn shrinkage referred to by the questioner. Again, STARFISH could be employed to develop a new fabric which, after mercerising, would give the required properties.

KNITTING TO SPECIFICATION

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1. INTRODUCTION

In countries where large organisations dominate the garment retailing industry, fabric production specifications are often imposed by these companies on the manufacturers who supply them in an effort to ensure consistency of quality and performance in their product ranges.

Even when the customer does not impose his own production specification on the knitter and/or finisher he will invariably demand certain dimensional and performance standards of the finished fabric or garment. In this case, the fabric manufacturer will, of necessity, have to develop his own production specification for each fabric quality in his range to enable their reproduction according to his customers requirements.

Normally speaking, therefore, the production of all fabrics is governed by a specification. In the first place this must contain sufficient basic information to enable the fabric to be produced.

For the knitter this must include details of the construction, i.e.

- interlock, rib or single jersey
- stitch length
- yarn count and type - single or twofold, combed or carded
- machinery - diameter, gauge, number of needles, etc.

(Diagram 1)

For the finisher this must include information regarding the final dimensions and performance criteria on which the finished fabric will be judged acceptable by the customers (Diagram 2), i.e.

- finished width
- finished length
- finished weight
- maximum amount of length and width shrinkage allowed to a specified test

Regardless of who sets the production specifications, however, once they have been developed for a particular fabric quality, to the satisfaction of both the manufacturer and the customer, it is of the utmost importance that they are adhered to if the performance of the finished fabric or garment is to be consistently maintained.

One of the most persistent problems facing the cotton knitgoods manufacturer is how to produce fabrics with low residual shrinkage and garments which are dimensionally stable in laundering and wear.

Invariably, if this is not achieved, both the knitter and the customer blame the dyer and finisher. In reality, this can be unjust as usually the finisher has no direct control over the supply of fabric from the knitter, and the finishing performance targets, he will always try and achieve, are often imposed by the customer. If either or both are inconsistent or unrealistic in their supply or specification the consequences are, invariably, high levels of residual shrinkage and loss of performance and the finisher gets the blame. That is not to say that the finisher does not and cannot influence the situation, but it should be understood from the outset that the production of high quality, dimensionally stable knitted cotton fabrics is a team effort which requires co-operation and close communication between knitter - finisher - garment manufacturer - and customer if it is to be achieved. However, because the knitter, as the fabric manufacturer, is at the head of the production chain, overcoming the problem of fabric shrinkage starts with him.

To explain and justify that statement I must briefly refer back to some of the points made in the previous paper.

Shrinkage, simply defined, is the change in fabric or garment dimensions brought about by some relaxation process which enables the strains and distortions imposed on the fabric during manufacture and processing to be released, thereby allowing the fabric to take up a stable relaxed configuration. Unfortunately, as has already been pointed out, different methods of relaxation can give different results. (Diagram 3)

Therefore, if we are going to be able to understand how the problem of shrinkage can be overcome we have first to decide on a reliable and reproducible method for bringing all fabrics to an equivalent state of relaxation for comparison. This will then become our reference state on which all measurements and comparisons can be made.

At IIC we have settled on a relaxation method which contains consecutive cycles of washing or wetting out, followed by tumble drying. (Diagram 4)

Once we have defined a reference state on which to make measurements some of the reasons why shrinkage has been a perennial problem can begin to be understood.

Shrinkage can now be redefined, in terms of our relaxation procedure, as the difference in dimensions between the finished fabric and its dimensions in the reference state. If the dimensions of the finished fabric are fixed by the customer, that is fabric width or wale density, and fabric length or course density, then it becomes obvious that any variation in the reference dimensions, for whatever reason, will result in variation in shrinkage. However, as the reference dimensions of a knitted fabric are, in the first instance, determined by the knitters choice of stitch length, yarn count and type, and the knitting machine on which he produces the fabric, any variation which he allows in these parameters will result in a change in the reference dimensions and this can affect the level of residual shrinkage in the finished fabric. Consequently overcoming the problem of fabric shrinkage starts with the knitter. (Diagram 5)

The concept that the knitter fixes the relaxed dimensions of a fabric by his choice of stitch length and yarn count is not new. Many research workers over the years have studied the geometry of knitted fabrics in various states of relaxation and have all concluded, as far as I am aware, that the length of yarn in the knitted loop is the main constructional variable affecting relaxed dimensions. Some have also proposed, both from theoretical and practical experimentation, that the yarn count, or more specifically the yarn diameter, can also have an influence, although most have considered that the degree to which it affects dimensions is comparatively small when compared with the influence of stitch length. The majority of previous studies have, however, been limited in one or more important areas.

Much of the early work on fabric geometry was carried out on fabrics made from fibres other than cotton; most of the studies were restricted by time, budget or equipment in the number and range of different structures and qualities which could be examined; invariably the trials were small scale, and finally and perhaps most significantly, practically all the work was carried out on greige fabrics or fabrics which had received only a minimum finishing treatment. Consequently, the main conclusions have been that once the relaxed dimensions of a given greige fabric have been established - by whatever method of relaxation was chosen - they remain fixed, and the fabric, irrespective of further processing, will always try to return to this relaxed stable state during any subsequent relaxation or laundering procedure. (Diagram 6)

However, although the reference dimensions of greige state knitted cotton fabrics are determined by the knitter, primarily by his choice of stitch length and yarn count, the reference dimensions of the same fabric after a commercial dyeing and finishing treatment are quite different.

Diagrams 7 - 9 show, in terms of course and wale density and fabric weight, the influence of one particular finishing route on the reference dimensions of a range of 20G interlock fabrics, knitted at a series of different stitch lengths from the same yarn - Ne 1/38, compared with their greige reference dimensions. The influence of stitch length on reference dimensions is also clearly shown.

In this example (diagram 7) the effect of finishing is to decrease the number of courses in the fabric in the reference state. In other words, these fabrics after dyeing and finishing are naturally longer than when measured in the greige reference state.

In this example (diagram 8) the effect of finishing is to increase the number of wales in the fabric in the reference state, which means that these fabrics are naturally narrower after dyeing and finishing, than when measured in the greige reference state.

Finally, in terms of fabric weight per unit area these fabrics after dyeing and finishing are naturally lighter in the reference state when compared with greige (diagram 9).

A proportion of the differences in dimensions illustrated can be explained by alterations in the stitch length (due to yarn shrinkage) and the yarn count, but these changes alone are inadequate to totally explain all the dimensional differences which are apparent. Consequently the conclusion must be that the dyeing and finishing route itself has imparted a permanent change in the reference dimensions of the fabric, independently of the knitter. It is therefore essential that the effect of variations in stitch length and yarn count are viewed in terms of their influence on final finished dimensions and not just on greige dimensions.

You will have noticed that although dyeing and finishing can independently alter the reference dimensions of a given fabric - and this point will be discussed more fully in later papers - the influence of this particular finishing route is fairly consistent over the range of commercial qualities. Therefore, the fact that the finishing route can have an influence does not in itself absolve the knitter from all responsibility and my original point still holds true - that initially the knitter determines the reference dimensions of any given quality by his choice of stitch length, yarn count and machinery - and any variation in the reference dimensions of a fabric - if that fabric is finished in the same way to the same specification, will result in variation in shrinkage.

2. THE INFLUNCE OF STITCH LENGTH - VARIATION AND QUALITY CONTROL

As I have previously stated, the length of yarn in the knitted loop is one of the major variables in the production of a knitted fabric which can influence its reference dimensions. It is therefore essential that variations in stitch length are kept to a minimum, and that stitch length is maintained uniformly and consistently throughout the production of a particular fabric quality.

The only reliable and consistent way to ensure that every needle in every revolution of the knitting machine is knitting the same stitch length is by means of a positive feed system which enables a predetermined length of yarn to be fed positively and consistently to all the needles for each revolution of the machine cylinder.

This predetermined length of yarn is commonly referred to as course length; that is the length of yarn per needle or stitch multiplied by the number of needles knitting per revolution in the cylinder or cylinder and dial.

From the practical knitting point of view it is obvious that attention also needs to be paid to the levelling and setting of each individual stitch cam, yarn input tensions, take-down and stretcher board settings, etc. if for example maximum knitting efficiency and minimum fault rates are to be achieved, but with respect to final fabric performance the accurate maintenance of stitch length is the most important knitting variable to control.

To be fully effective, however, regular monitoring of course length is necessary as some variation is both inevitable and unavoidable.

There are many instruments currently available which have been developed specifically to enable the knitter to accurately monitor and control course length or stitch length on the knitting machine - from the original simple mechanical device developed by HATRA in the 1950's to the more sophisticated electronic devices that are available today.

Like most machines, however, any instrument can only operate within certain specific degrees of accuracy - that is within the technical limitations of its manufacture - and from time to time they can also go wrong.

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Like most machines, however, any instrument can only operate within certain specific degrees of accuracy - that is within the technical limitations of its manufacture - and from time to time they can also go wrong.

In our experience so far, and during the course of our knitgoods programmes, we have had the opportunity to evaluate several different instruments. All these instruments reliably give consistent and reproducible measurements of course length, within the manufacturers tolerances. For most modern devices this is usually ±1%, although accuracy figures ranging from ±0.1% to ±2% have also been quoted by some manufacturers.

However although individually each instrument may perform satisfactorily, different instruments can give different readings for course length when compared with each other.

This point can be illustrated by the results of a trial we carried out in our laboratory (diagram 10).

On three separate occasions, using two different instruments, individual measurements of course length were made on five different feeders, selected at random round our 24 gauge single jersey machine. The yarn remained the same throughout the trials and the speed of the machine is fixed by the gearing. After each series of measurements a piece of fabric was removed from the machine and submitted to the laboratory for testing. The average readings for stitch length obtained from each instrument are seen plotted here along with the average stitch length in the fabric as measured in the laboratory.

You can see that instrument 1 is consistently recording a higher measurement for stitch length than was measured in the fabric while instrument 2 is consistently recording a lower measurement. Although individually each instrument is self consistent, on every occasion each is recording a different stitch length both in terms of what was actually measured in the fabric and also from each other. This experiment was repeated on 28G and 18G machines for both tight and slack qualities and similar results were obtained.

Consequently, if different manufacturers are producing fabric to the same nominal specification and are using different instruments, or even if one manufacturer is using more than one instrument, there is a possibility that the fabric being received by the finisher - although nominally of the same construction - may be dissimilar in terms of stitch length.

The results of this initial experiment have since been confirmed by mill trials.

Two companies both producing 14 gauge 1 x 1 rib fabric to the same specification allowed us to take samples of greige fabric from their standard production on twelve separate occasions. You can see from the diagram 11 that company A was producing fabric with a consistently longer stitch length than company B. On average the stitch length measured in the fabrics obtained from company A was 1.4% longer than target, while the stitch length recorded in the fabric obtained from company B was on average 0.7% shorter than target.

Therefore although both companies are producing fabric to specification within the tolerance laid down of ±2.5%, they are consistently producing fabrics dissimilar to each other. On average the difference between the two companies is 2.1% but the maximum difference is as large as 3.9%.

The consequence of this for the customer, if all the fabrics from both sources are finished to the same finished fabric specification, is that he will be receiving fabrics with variable and consistently different levels of shrinkage.

The consequence for the knitter who is using an instrument that consistently underestimates the amount of yarn going into a fabric, is financial. He is using more yarn to meet the required knitting specification than is necessary.

It is therefore good practise for any knitter attempting to produce consistent greige cloth to a specification to monitor both his instruments and his production on a regular basis by comparison with a standard laboratory test for stitch length measured in the fabric.

If this is done on a regular basis it benefits both the knitter and the customer.

Firstly, it ensures that the correct interpretation of the numbers reported by the instrument - that is what they really mean in terms of stitch length in the fabric - which enables the knitter to determine the accuracy and variability of his instrument and consequently ensures that any drift in production due to the instrument becoming faulty or out of calibration is noticed quickly, allowing remedial action to be taken before large quantities of fabric are produced with an incorrect stitch length. (Diagram 12)

Secondly, it enables the knitter to establish the consistency with which his fabrics are being produced, and the spread of normal variation in properties and performance due to variation in stitch length to be expected, while providing the means of ensuring that, on average, his fabrics are being produced as close to specification as possible.

Thirdly, it enables the knitter to establish realistic tolerances for stitch length in his production specification which take into account the unavoidable variations due to the limitations of his instruments, machinery, etc. while keeping avoidable variation due to bad quality control, incorrect knitting, etc to a minimum.

Finally, it serves as a useful means of communication between manufacturer and customer. The knitter can ensure that his customer is not asking for the impossible by specifying stitch length more closely than is practical, and the customer can ensure that having set and agreed a realistic specification he has a sound basis for complaint if his supplier or suppliers deliver variable products.

3. THE INFLUENCE OF YARN COUNT - VARIATION AND QUALITY CONTROL

The second most important variable which can affect the reference dimensions of a fabric is the count and type of yarn used in its manufacture. For example, singles yarn as opposed to two-fold yarn.

In diagrams 13 - 15 the reference dimensions of a range of identically knitted and finished fabrics are compared. The only difference is that one set was knitted from singles yarn Ne 1/28, and the other set from two-fold yarn Ne 2/56.

In diagram 13 you can see that the fabrics knitted from two-fold yarn have less wales/unit length than the equivalent fabrics knitted from singles yarns - therefore they are naturally wider.

In diagram 14 the fabrics knitted from two-fold yarn have less courses per unit length than the equivalent fabrics knitted from singles yarn - therefore they are naturally longer.

Finally, the fabrics shown in diagram 15 are knitted from two-fold yarn and are naturally lighter than those produced from singles yarn.

The potential influence on residual shrinkage if these fabrics are finished to the same dimensions should therefore be obvious.

It is possible that similar differences may be detected between yarns produced by different spinning systems, e.g. rotor spun compared to ring spun; or yarns produced from different fibre varieties; or whether the yarn is carded or combed. But so far, we have had neither the time or the opportunity to study these possibilities in a systematic way.

Therefore for the moment possible variation in fabric dimensions from these sources cannot be specifically identified.

Notwithstanding the potential influence of different fibres, spinning systems or the differences between singles and two-fold yarns, the reference dimensions and finished performance of a fabric can also be affected by variations in yarn count. Unlike stitch length, however, variations in yarn count are much more difficult for the knitter to control, as he is almost entirely dependent on his yarn supplier. For this reason, it is essential that the knitter develops good communications with his spinner so that the spinner is fully aware of the influence that large variations in his production can have on the final quality and performance of the knitted fabric.

One of the main problems for the knitter in ensuring consistency of supply is that normally, for commercial reasons - availability, price, etc - more than one source of yarn is used and even though the same nominal count may be specified - due to the influence of variations in the spinning process - the average count delivered by each supplier may not be the same.

Sampling of commercial production from several knitgoods manufacturers have confirmed that variation within and between yarn suppliers can indeed be quite large.

For example, samples of yarn and greige fabric were collected over a period of approximately six months from the standard production of two knitters producing 20 gauge interlock fabric to the same specification. Several sources of yarn were sampled during this period, all supplying to the same yarn specification, Ne 1/38 ±2.5%, for the same fabric quality. (Diagram 16)

The results obtained from three of the spinners sampled are illustrated here.

Spinner A was supplying yarn with low variability but the average count delivered was nearly 1½ counts coarser than specified.

Spinner B was supplying yarn with a somewhat higher variation but the average was close to the count specified.

Spinner C on the other hand was supplying yarn with a much higher count variation although on average the mean count was only ½ a count finer than specified.

Therefore, although the tolerance on yarn count for this fabric specification was ±2.5%, due to the inconsistencies of the various suppliers, the actual maximum variation observed was found to be nearly double that allowed.

This level of yarn count variation can have a significant effect on the final dimensions, properties and performance of a finished fabric.

Variation in yarn count between fabrics knitted to the same stitch length directly affects the reference weight of those fabrics. A variation in yarn count of ±2.5% between a number of fabrics knitted to the same specified stitch length will translate, almost directly to a comparable variation in the reference weight of those fabrics. (Diagram 17)

Using the example of the three spinners shown in diagram 16, fabrics produced from the average deliveries of spinner A will have a reference weight of approximately 225 gsm, while fabrics produced from the average deliveries from spinner C will have a reference weight of approximately 215 gsm - a variation in weight compared to the weight expected from the nominal yarn of 4.6%. If, however, fabrics are produced from yarn delivered with an average count at the extremes of the variation found - and from time to time this may happen - the potential range in fabric weight between pieces will be much greater. From approximately 209 gsm to 228 gsm or an 8.7% variation based on the nominal reference weight of 217 gsm. This variation in final fabric properties is directly due to the influence of variations in average yarn count and takes no account of the other sources of variation in the production and processing of a knitted fabric. However, as fabric weight bears a direct relation to fabric cost obviously therefore both the knitter and the customer would prefer to keep variation in finished fabric weight to a minimum. Consequently, if these fabrics are then finished to a constant weight, and a constant width - and this is not an unusual practise, especially in open width processing, the variations in fabric weight and dimensions due to variations in yarn count are transferred into variations in residual shrinkage in the finished fabric.

For example if winch processed 20 gauge interlock fabrics knitted on a machine with 1500 needles to a stitch length of 3.38 mm, are finished to a constant width of 118 cm and a constant weight of 165 gsm, and average yarn count between pieces varies by ±2.5%, potential fabric shrinkage will vary between 8.8 and 14.1% in length and between 13.2 and 14.6% in width. Larger variations in average count will obviously lead to larger variations in fabric shrinkage.

Therefore, although commercially it is unrealistic to suggest that the finisher can control his processing so accurately that he will always be able to deliver constant weight and width - he will always try if that is the specification laid down by his customer. Therefore the knitter must be aware that if he allows large variations in average count between fabric pieces of the same quality he must expect that either fabric weight and therefore cost will vary if the fabric is finished to specified dimensions or fabric shrinkage and therefore performance will vary if a constant finished fabric weight is maintained. (Diagram 18)

The knitter is obviously therefore very reliant on his supplier or suppliers to operate good quality control systems within the spinning mill.

But what can he do to try to ensure that his suppliers are actually delivering consistently the yarn count specified?

Large scale testing for yarn count is obviously very expensive in both time, personnel and equipment. Yet some form of quality control is obviously necessary if consistent fabric quality is to be achieved. Therefore, because of necessity the amount of yarn testing that can be carried out has to be limited, meaninful results can only be obtained over a fairly long period of time.

If a limited number of cones, for example 10, are sampled at random, from each delivery from each supplier and are checked for yarn count, over a period, the knitter will be able to arrive at certain conclusions regarding the ability of his suppliers to deliver the average count specified, and obtain an idea of the variation within and between suppliers. This will enable him to establish the level of variability normally to be expected both in his yarn and in his fabric.

A new or prospective supplier would obviously be subjected to a much more rigorous evaluation before acceptance, but for existing satisfactory suppliers a limited approach has several advantages.

In the first place, if it is not unduly expensive, and limited testing should also ideally be carried out to monitor yarn friction and also possibly twist as they affect knitting efficiency and quality. (Diagram 19)

Secondly, it establishes for each of his suppliers the actual count being delivered and the consistency with which they are delivering it, thereby providing the knitter with information about the normal variation within and between deliveries which he must expect which enables tolerance standards to be set. It also keeps the spinners alert if they know their production is being monitored by their customer they are more likely to pay extra attention to their own quality control.

Thirdly, it enables the knitter to identify the overall range in average count he can expect which gives him an indication of the total range of variation he must accept in his fabric production and this assists him to establish realistic tolerances on his production specifications.

Finally, it provides a means of communication between the knitter and his suppliers and the knitter and his customers. By assisting in the setting of commercially realistic and attainable specifications and tolerances on raw materials and output which take into account the unavoidable variations in yarn and fabric production.

SPIRALITY - SPECIAL PROBLEM IN SINGLE JERSEY

In any discussions of yarn quality and the influence it can have on the final dimensions and performance of a product, the special problem of spirality in single jersey fabrics cannot be ignored.

Fabric spirality is described by the size of the angle made between the wales and a line drawn perpendicular to the courses. For single jersey knitters and finishers it is at least as big a problem to overcome as residual shrinkage and if the fabric must be constructed from singles yarns there are no easy solutions.

Spirality in a fabric is caused by the relaxation of torsional forces in the yarn which cause the individual fibres, twisted round each other during spinning, to try and return to their original untwisted state. In yarn this is seen as twist liveliness, the snarling and twisting of a yarn on itself when two ends are brought slowly together.

In an unbalanced fabric construction like plain single jersey this affect causes the knitted loops to distort, twist and incline out of the plain of the fabric.

For yarns of similar quality (fibre, processing, spinning systems, etc) the twist liveliness of the yarn can be related to the amount of twist or turns per unit length put into the yarn during spinning. Yarns with lower turns/unit length tend to develop less spirality in the fabric than yarns with high twist levels. (Diagram 20)

The number of turns/unit length in a yarn is determined by the twist factor to which it is spun.

Twist factor is a function of the number of turns/unit length and the square root of yarn linear density. For the same twist factor therefore finer yarns have a relatively higher number of turns/unit length than coarser yarns. Consequently fabrics made from finer yarns develop comparatively higher levels of spirality than those produced from coarser yarns.

The second influence on fabric spirality is the stitch length or relative tightness at which a fabric is knitted. A fabric produced with a shorter stitch length for a given yarn count will develop less spirality when compared to a fabric produced from the same yarn at a longer stitch length.

Comparatively therefore a fabric knitted from a coarser yarn knitted with a relatively short stitch length will develop less spirality than a finer yarn knitted with a relatively long stitch length.

The direction of twist in a yarn is also considered by some to influence the amount of spirality in a fabric. However, we have not found that there is a significant reduction in the amount of fabric spirality which develops when fabrics knitted to the same stitch length from yarns of the same count but of equal and opposite twist are compared - the change is only in the direction of spiral, i.e. Z twist yarns spiral to the right, S twist yarns spiral to the left.

Single jersey fabrics knitted from two-fold yarns do not however tend to develop significant levels of spirality. This is due to the fact that the folding twist is usually in the opposite direction to the twist in the component singles yarns and therefore the opposing forces are balanced, and normally the residual twist liveliness in the yarn is very low. Any small amount of spirality which may develop will be in the direction of the residual twist that is to the right or positive spirality for Z twist yarn or to the left or negative spirality for S twist yarn.

The other method of eliminating spirality is by knitting alternate ends of S and Z twist yarn of equal but opposite twist level. Spirality is in this way alleviated but usually at the expense of appearance, which, as can be seen, is uneven and irregular as the loops in each course distort in opposite directions. In addition, the reference dimensions of fabrics knitted from alternate S and Z twist yarns are different when compared to similar fabrics produced from all Z twist yarn or all S twist yarn. Therefore, in addition to the loss in appearance, finishing targets for this fabric also need to be amended if similar performance levels are to be achieved.

In addition there are also extra problems created in yarn storage and quality control to ensure that yarns of opposite twist are not inadvertently mixed.

The level of spirality in a fabric is generally reduced by finishing. The angle of spirality in the finished reference state tends to be lower than in the equivalent greige reference state. This is presumably due to the release of stress in the twisted fibres brought about by the swelling and mechanical agitation received during wet processing and also some processes appear to influence stress release more efficiently than others.

The control of fabric spirality is therefore similar to shrinkage, a team effort. The knitter contributes by his choice of yarn and stitch length, taking into account the influence of both, and the effect of variation in either in terms of final dimensions, and the finisher can contribute by the method of finishing he may choose to adopt.

COMBINED INFLUENCE OF VARIATIONS IN STITCH LENGTH AND YARN COUNT

So far, I have talked about the effect of variations in stitch length and yarn count on the reference dimensions of finished fabrics almost as if their effects are completely independent of each other. This is obviously not the case and during the course of normal production there will be occasions when the variation in one parameter will be affecting dimensions in one direction while variations in the other are working in the opposite direction, therefore, compensating for each other. Conversely from time to time the variations will work additively creating a larger effect on reference dimensions than would normally be expected.

We therefore have to look at what the effect will be on finished fabric reference dimensions of combined variations in greige stitch length and yarn count.

In the UK a normal commercial specification for stitch length includes an allowed tolerance of ±2.5% and given adequate quality control by all manufacturers this level of tolerance can realistically be achieved. Individually, knitters should be able to achieve somewhat better results but for example if a retail organisation is buying fabric from several sources, an allowance of ±2.5% on specification is not an unreasonable expectation.

Similarly, the normal commercial specification for yarn includes an allowed count variation of ±2.5% although this is far less likely to be achieved commercially, even by one fabric manufacturer because he is drawing yarn from several sources.

However, let us consider what the effect on reference dimensions will be assuming we can control stitch length and yarn count to within ±2.5%.

The maximum effect on relaxed dimensions and consequently final fabric performance if both stitch length and yarn count vary by ±2.5% on specification is shown in diagram 21. For a winch dyed 20G interlock fabric knitted at a nominal stitch length of 3.38mm and a nominal yarn count of Ne 1/38, reference courses/3cm vary from between 44.4 - 46.8 and reference wales vary between 42.9 and 44.4/3cm.

If these fabrics are finished to exactly the same dimensions of length and width the effect on shrinkage can be calculated. For example if the finished dimensions of the nominal fabric 1/38 at 338 are specified at 40 courses/3cm and 38 wales/3cm and if fabric shrinkage is calculated from the change in courses and wales from as delivered to the reference state the maximum effect on potential length shrinkage is in the range 10 - 14.5% and in width shrinkage between 11.4 and 14.4%.

If however yarn count varies by ±5%, and this as we have seen previously is certainly possible, the effect on relaxed dimensions and therefore shrinkage, is even larger - between 9.3 - 15.1% in length and between 10.3 and 15% in width.

Consequently, even when variations in yarn and stitch length can be maintained within reasonable commercial limits the effect on reference dimensions and therefore final performance is clear and it is therefore not surprising that fabric shrinkage and dimensional instability has been and is such a problem.

INFLUENCE OF MACHINERY

The third and final major cause of dimensional and performance problems in knitted fabric which is within the power of the knitter to control, is the choice of knitting machine.

Everyone, I am sure, is fully aware that the width of a fabric is determined by the number of wales/unit length and the number of needles in the knitting machine.

However, knitting machinery is often specified in terms of gauge and diameter only without particular reference to the number of needles. Theoretically of course, machine gauge implies a certain number of needles per inch i.e. 20G = 20 needles/inch and therefore if the diameter of the machine is also specified, theoretically so also should be the total number of needles in the machine.

What is often overlooked however is that depending on the particular engineering requirements of the machine, patterning mechanisms, auxilliaries etc. the number of needles in a particular gauge/diameter of machine can vary. This applies not only between different manufacturers but equally within a range of machines produced by one manufacturer. Unfortunately, not all machinery builders automatically specify the number of needles per machine gauge and diameter in their brochures, and although it is normal practise for this information to be recorded somewhere on the machine, it is sometimes overlooked and specifications are set using the theoretical number of needles for a particular gauge and diameter of machine.

The differences in the number of needles between particular models and different gauge/diameter combinations are usually small but sometimes they can be quite large.

A few examples are given in diagram 22. If these differences are properly accounted for in the setting of fabric width specifications there is of course no problem, unfortunately however, quite often, they are not.

Machinery in a knitting mill is often mixed both in model and manufacturer and is therefore quite often differentiated by gauge and diameter only. Certainly between companies supplying nominally the same fabric quality, knitting machinery will vary.

Consequently if the width specifications are originally established for a machine with, for example, 1944 needles and fabrics are in fact produced on a machine with 1872 needles, the effect on width shrinkage should be clear. To achieve the width specified the fabric produced on the 1872 needle machine will have to be pulled out further away from its reference state than the same fabric produced on the 1944 needle machine, an additional effect on width shrinkage of approximately 3.8%.

Quite often also a knitter who is under commercial pressures to increase his production of a particular quality will deliberately make the decision to use a different machine. It is not unknown for knitters to supplement their 20G interlock production for example by using an 18G machine. Their reasoning, that if the same stitch length and yarn count is used there will be no difference in the fabric, is not incorrect if they alter their finished width specification to take into account the different number of needles in the 18G machine - but when this correction is not made the resultant finished fabric, although knitted to the same quality, will have a higher level of residual width shrinkage after finishing than the 20G fabric (Diagram 23)

The problem of getting the correct balance between quality/needles and width becomes most acute when the production of body width fabrics is considered. In this instance the relationship between knitting quality and needles for a particular fabric width is extremely critical in terms of garment sizing and performance.

It is very easy to understand why a manufacturer should try and produce two garment sizes from one particular machine diameter by finishing the fabrics to different widths, but although understandable the inevitable consequence will be loss of performance and inconsistency of quality.

Therefore, attention must be paid to the wales x needles calculation if width shrinkage is not going to vary excessively.

SUMMARY AND CONCLUSIONS

To summarise therefore - the production of dimensionally stable cotton knitgoods is not an easy task and there are certain unavoidable variations in their production which will affect performance levels. However, if action is taken the size of these variations can be controlled, within limits, and we have then gone someway towards achieving our objectives.

The knitter, as the fabric manufacturer, is at the head of the production chain and therefore the control of shrinkage starts with his ability to remove avoidable variations, and maintain consistent quality in the greige fabric.

By monitoring of the incoming yarn and close contact with dependable yarn suppliers he can eliminate excessive variation in his raw materials.

By accurate control and monitoring of stitch length he can ensure consistency in the quality of the fabric he is producing.

By being aware that changes in production machinery can change the ratio of needles/diameter/width for a given quality he can remove excessive variations in fabric width.

By maintaining close communications with his finisher and by being aware that variation in the greige fabric will influence the ability of the finisher to achieve specified performance targets from given finishing specifications he can influence variation in final performance.

By maintaining good communications with his customers he can ensure that they set or accept realistic tolerances on their production performance specifications, which take into account the unavoidable levels of variation due to raw material (yarn) production control (stitch length) and finishing, while maintaining commercially achievable targets.

By remembering that the production of high quality dimensionally stable cotton knitgoods is a team effort and each part of the production chain can have an influence on final performance - for good or bad.

Diagram 1

BASIC KNITTING SPECIFICATION

1. FABRIC TYPE
2. STITCH LENGTH
3. YARN COUNT AND TYPE
4. MACHINE TYPE AND SIZE (NEEDLES)

Diagram 2

BASIC FINISHED FABRIC SPECIFICATION

1. WIDTH – WALE DENSITY
2. LENGTH – COURSE DENSITY
3. WEIGHT – PER UNIT AREA
4. PERFORMANCE – SHRINKAGE

Diagram 3

SHRINKAGE:

CHANGE IN DIMENSIONS DUE TO RELAXATION

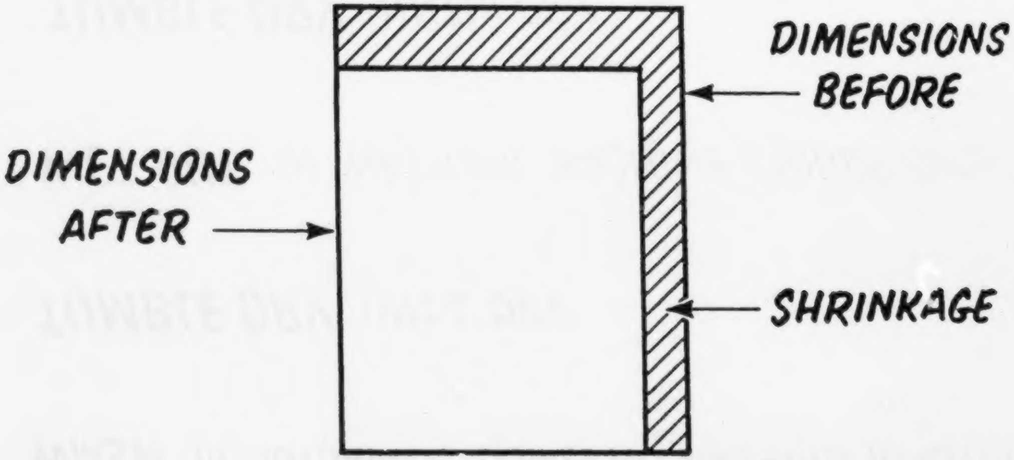

DIMENSIONS BEFORE
DIMENSIONS AFTER
SHRINKAGE

Diagram 4

TO ACHIEVE THE IIC REFERENCE STATE

1. **WASH** IN AUTOMATIC DOMESTIC WASHING MACHINE AT 60°C
2. **TUMBLE DRY** UNTIL DRY
3. **WET OUT** IN WASHING MACHINE (RINSE CYCLE)
4. **TUMBLE DRY** UNTIL DRY
5. **REPEAT** STEPS 3 AND 4 THREE MORE TIMES
6. **CONDITION**

Diagram 5

VARIATION IN REFERENCE DIMENSIONS EQUALS VARIATION IN SHRINKAGE

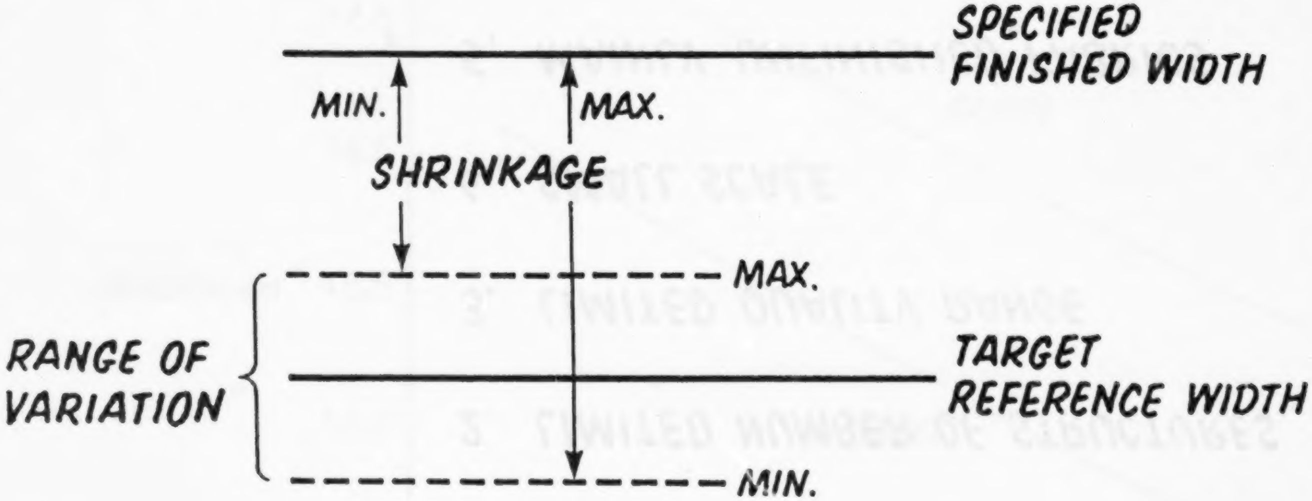

SPECIFIED
FINISHED WIDTH
MIN.
MAX.
SHRINKAGE
MAX.
RANGE OF
VARIATION
TARGET
REFERENCE WIDTH
MIN.

Diagram 6

LIMITATIONS OF PREVIOUS RESEARCH

1. FIBRES OTHER THAN COTTON
2. LIMITED NUMBER OF STRUCTURES
3. LIMITED QUALITY RANGE
4. SMALL SCALE
5. MAINLY UNFINISHED FABRICS

Diagram 7

20 GAUGE INTERLOCK Ne 1/38 JET DYED, ECOSOFT

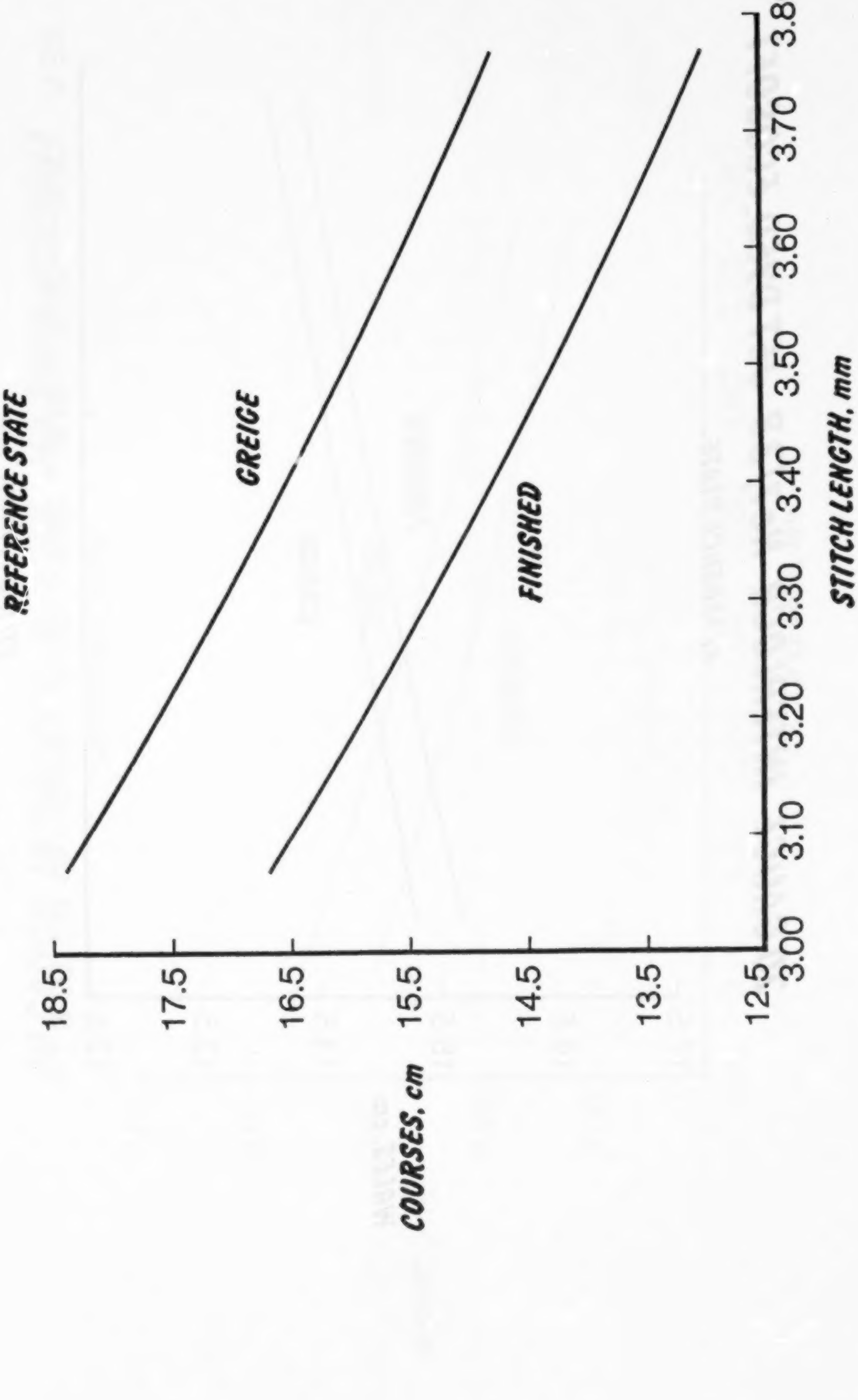
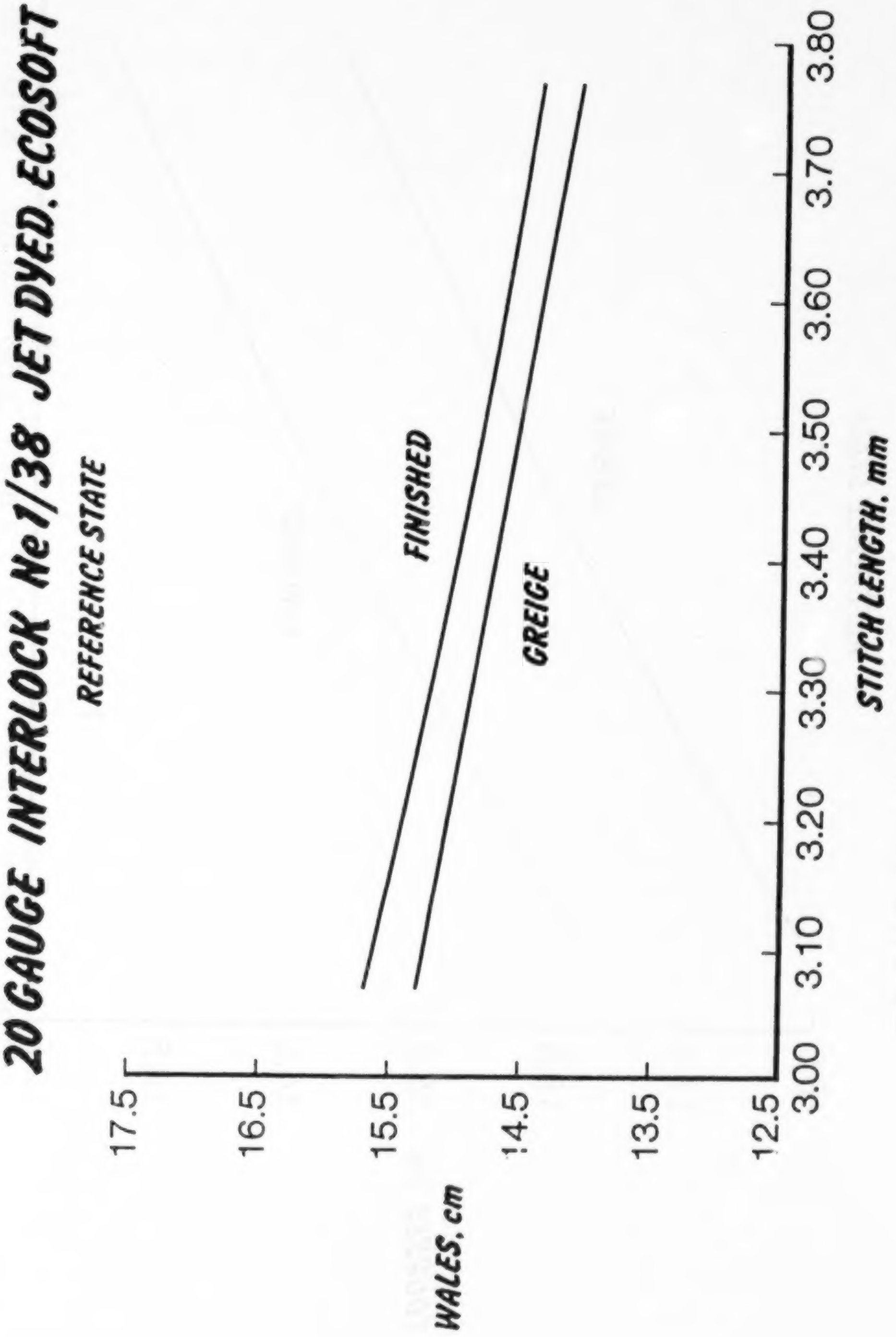


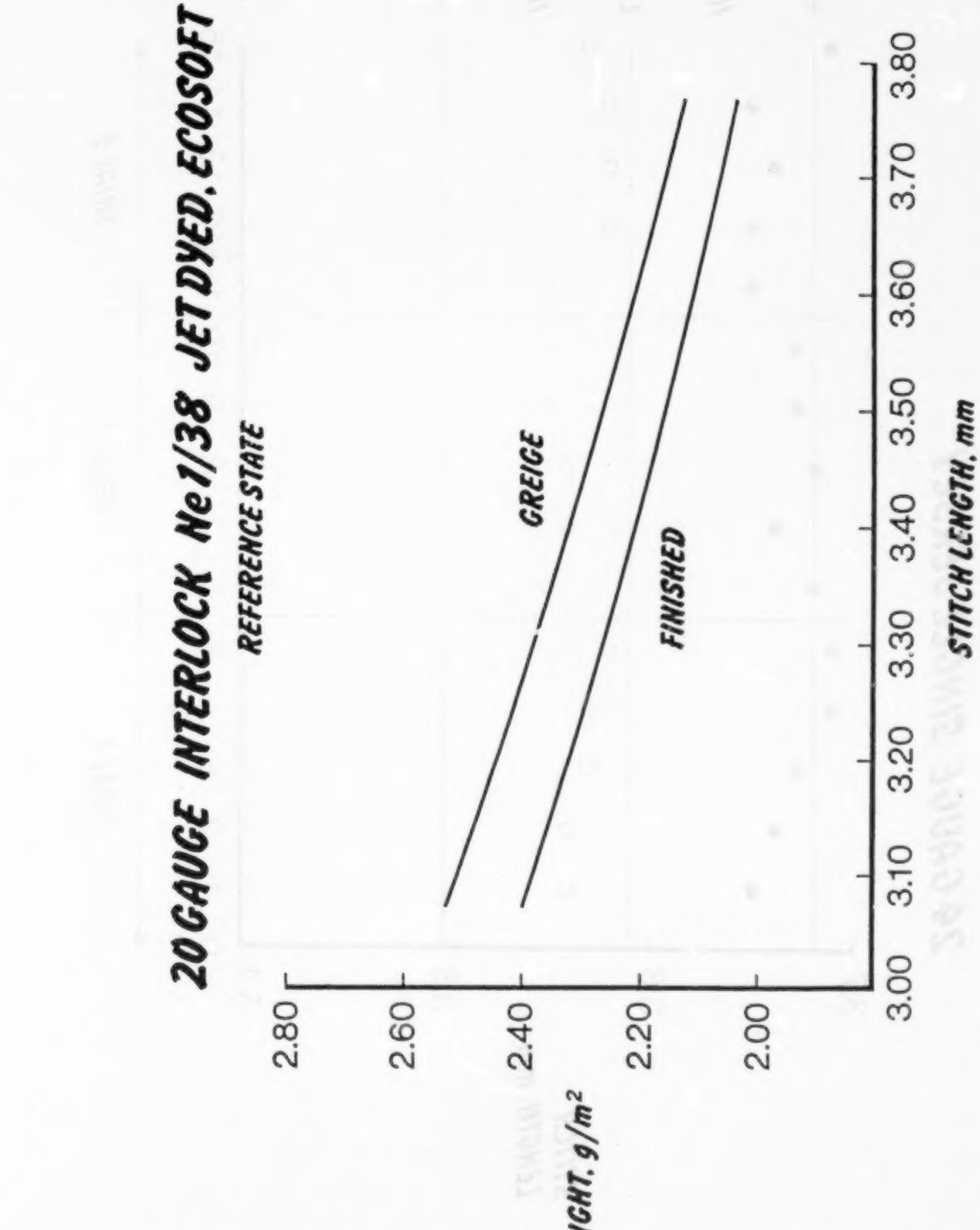
Diagram 8



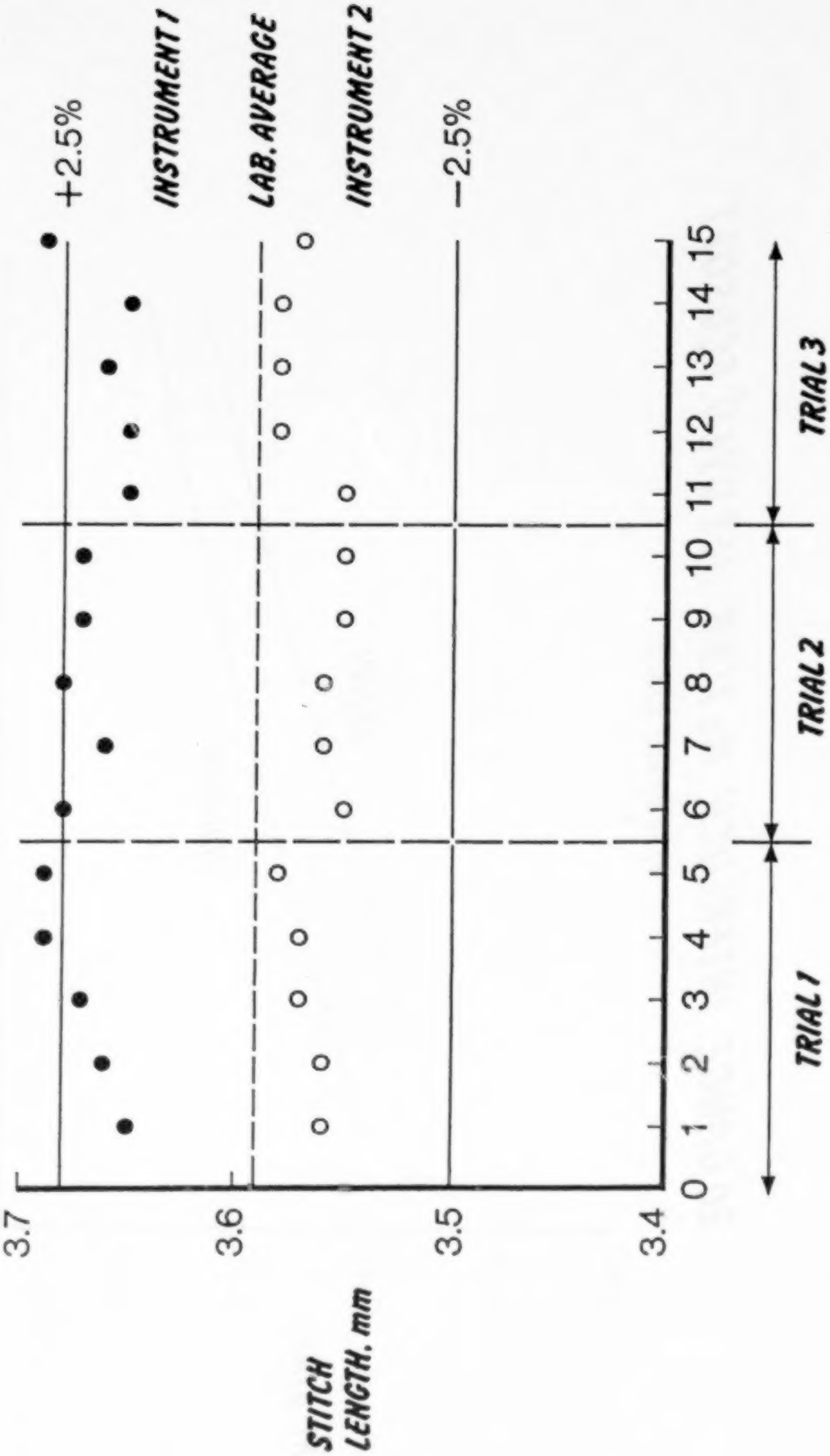
20 GAUGE INTERLOCK Ne 1/38 JET DYED, ECOSOFT

REFERENCE STATE

Diagram 9



20 GAUGE INTERLOCK Ne 1/38 JET DYED, ECOSOFT

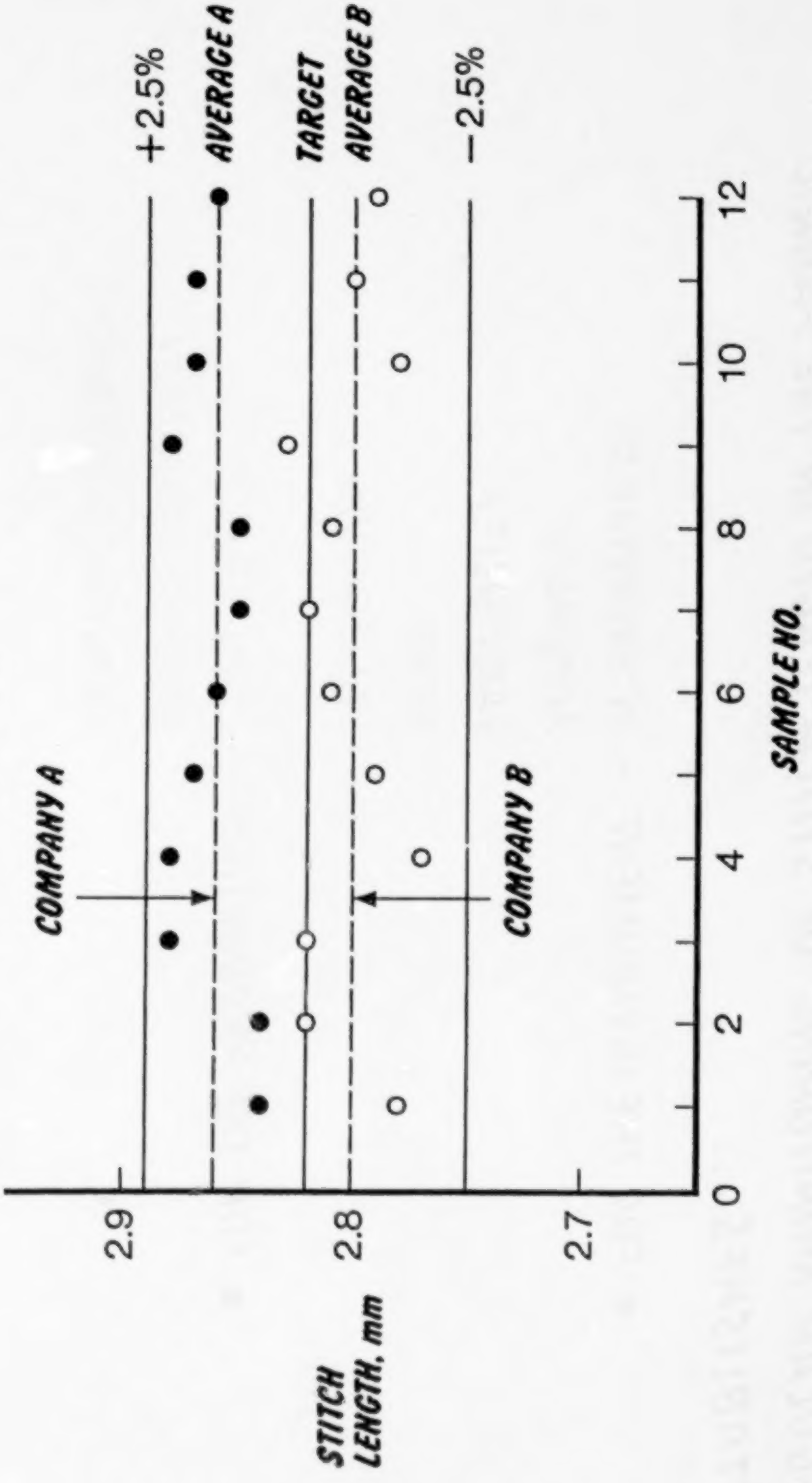


24 GAUGE SINGLE JERSEY

Diagram 11

14 GAUGE 1x1 RIB STITCH LENGTH SPECIFICATION

TARGET 2.82 mm TOLERANCE ± 2.5%



REGULAR MONITORING OF STITCH LENGTH IN THE FABRIC ESTABLISHES...

- FOR THE INSTRUMENT – INTERPRETATION
  - ACCURACY
  - VARIABILITY
  - DRIFT
  - CALIBRATION
- FOR THE PRODUCTION – CONSISTENCY
  - NORMAL VARIATION
  - REALISTIC TOLERANCES
- A MEANS OF COMMUNICATION

Diagram 13

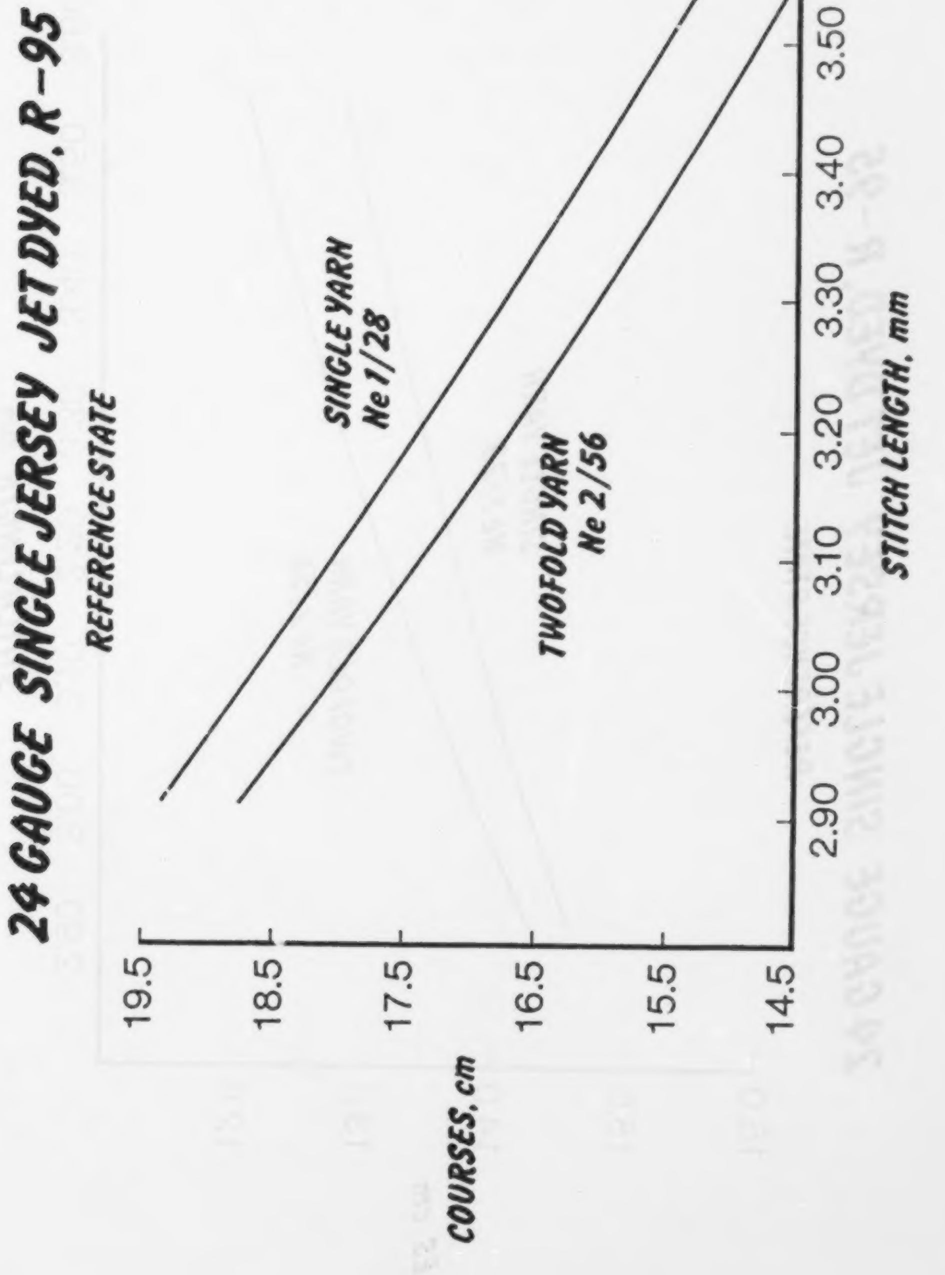

24 GAUGE SINGLE JERSEY JET DYED, R–95
REFERENCE STATE
SINGLE YARN
Ne 1/28
TWOFOLD YARN
Ne 2/56
COURSES, cm
19.5
18.5
17.5
16.5
15.5
14.5
2.90
3.00
3.10
3.20
3.30
3.40
3.50
3.60
STITCH LENGTH, mm

Diagram 14

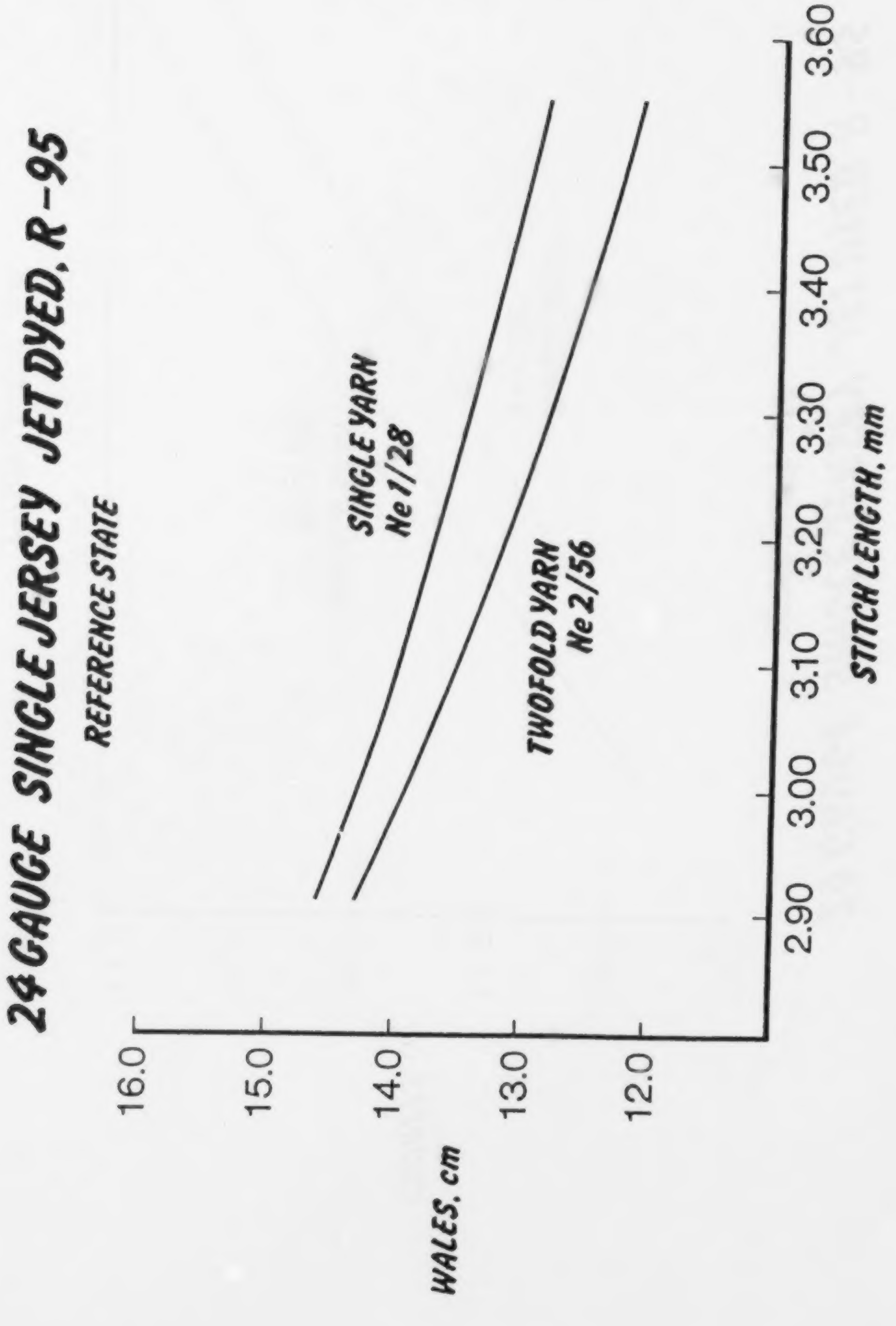

24 GAUGE SINGLE JERSEY JET DYED, R–95
REFERENCE STATE
SINGLE YARN
Ne 1/28
TWOFOLD YARN
Ne 2/56
WALES, cm
16.0
15.0
14.0
13.0
12.0
2.90
3.00
3.10
3.20
3.30
3.40
3.50
3.60
STITCH LENGTH, mm

Diagram 15

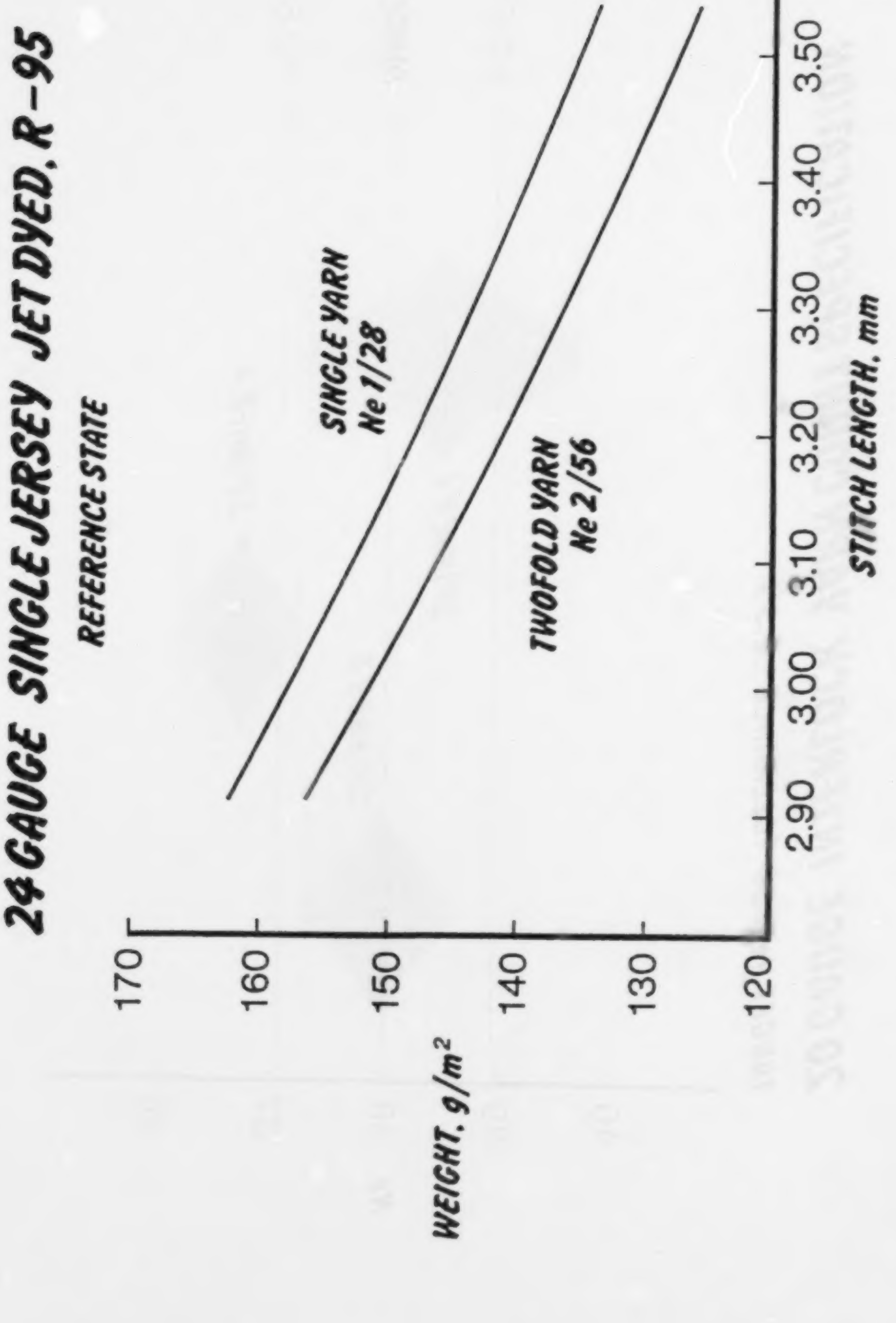
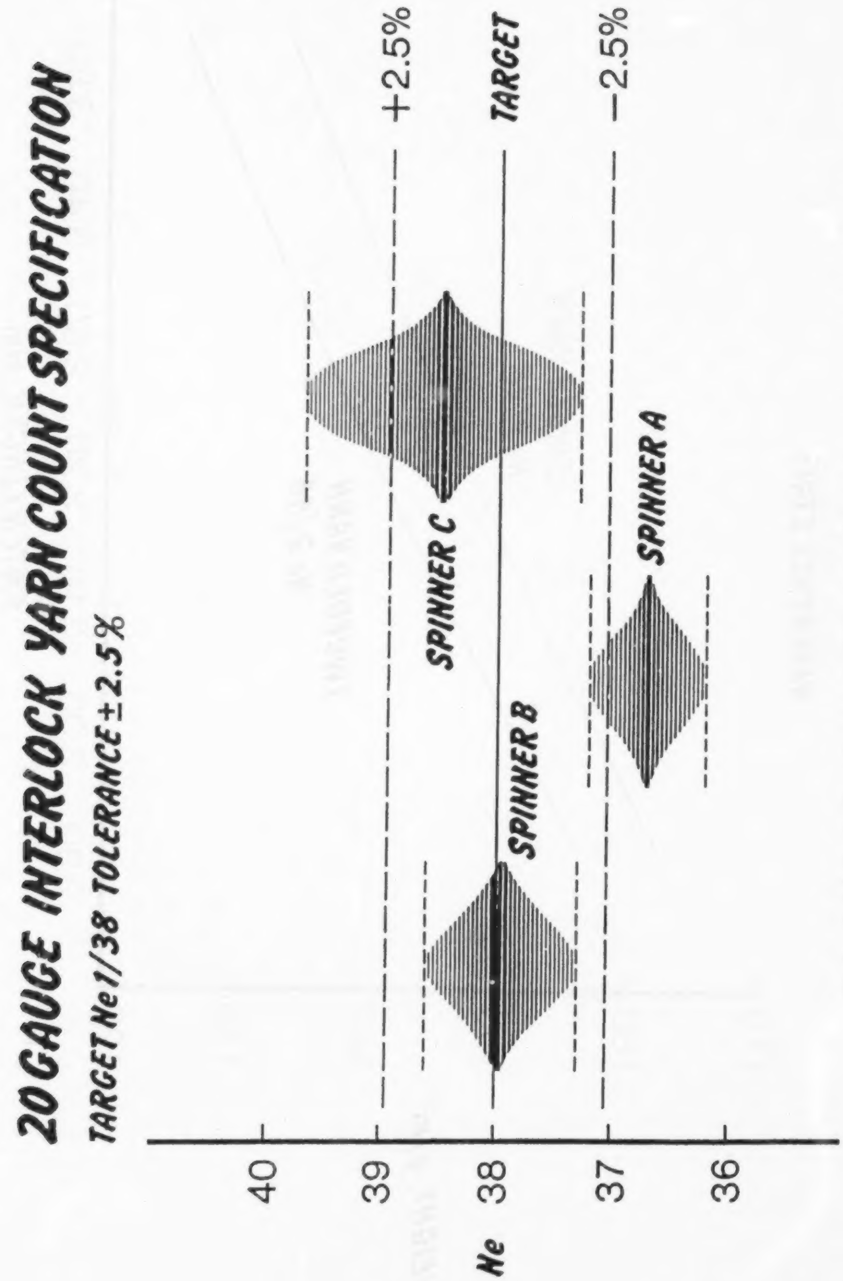

24 GAUGE SINGLE JERSEY JET DYED, R–95
REFERENCE STATE
SINGLE YARN
Ne 1/28
TWOFOLD YARN
Ne 2/56
WEIGHT, g/m²
170
160
150
140
130
120
STITCH LENGTH, mm
2.90
3.00
3.10
3.20
3.30
3.40
3.50
3.60

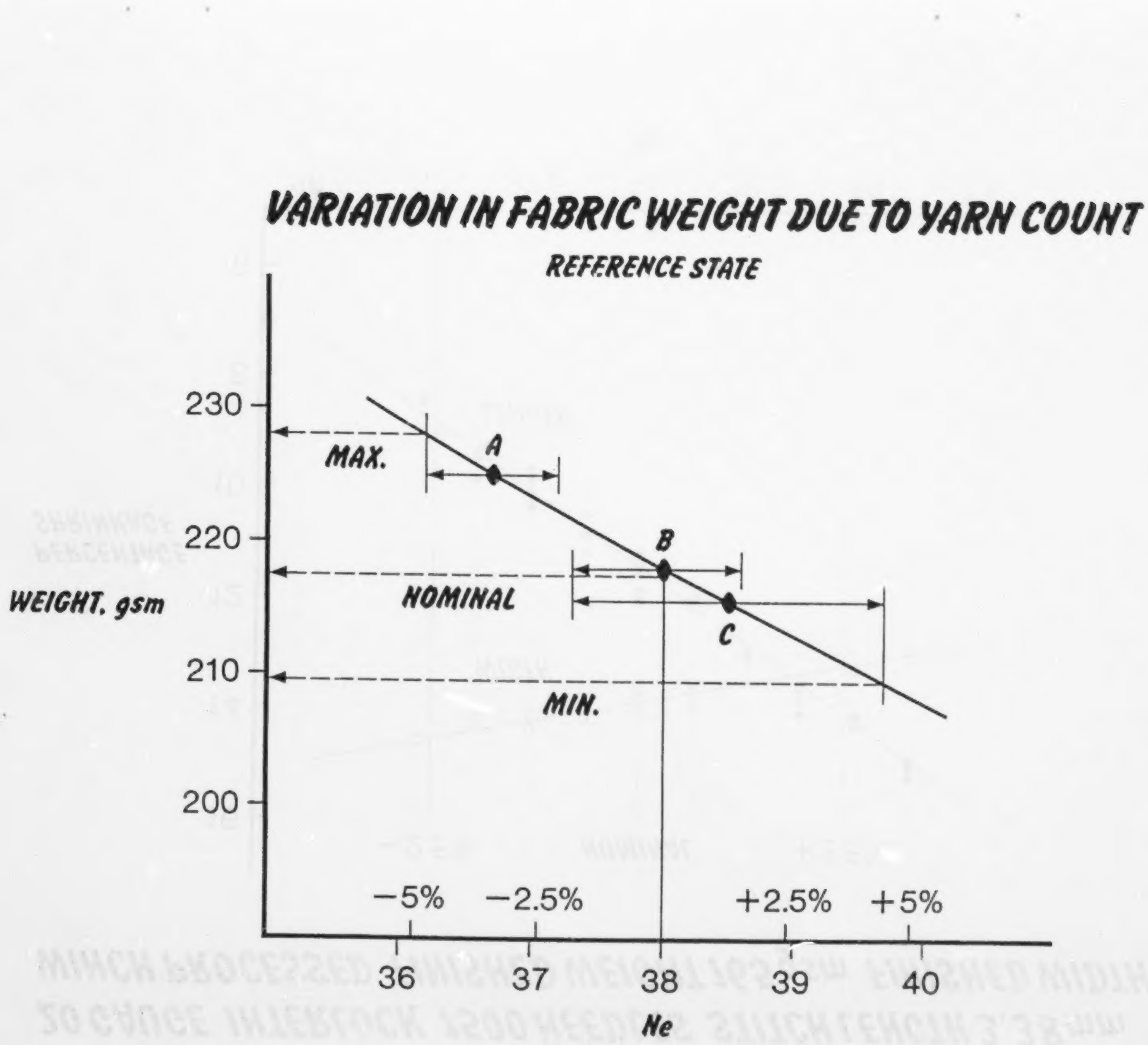
Diagram 16



20 GAUGE INTERLOCK YARN COUNT SPECIFICATION

TARGET Ne 1/38 TOLERANCE ± 2.5%

Diagram 17



VARIATION IN FABRIC WEIGHT DUE TO YARN COUNT

Diagram 18

20 GAUGE INTERLOCK 1500 NEEDLES STITCH LENGTH 3.38 mm
WINCH PROCESSED FINISHED WEIGHT 165 gsm FINISHED WIDTH 118 cm

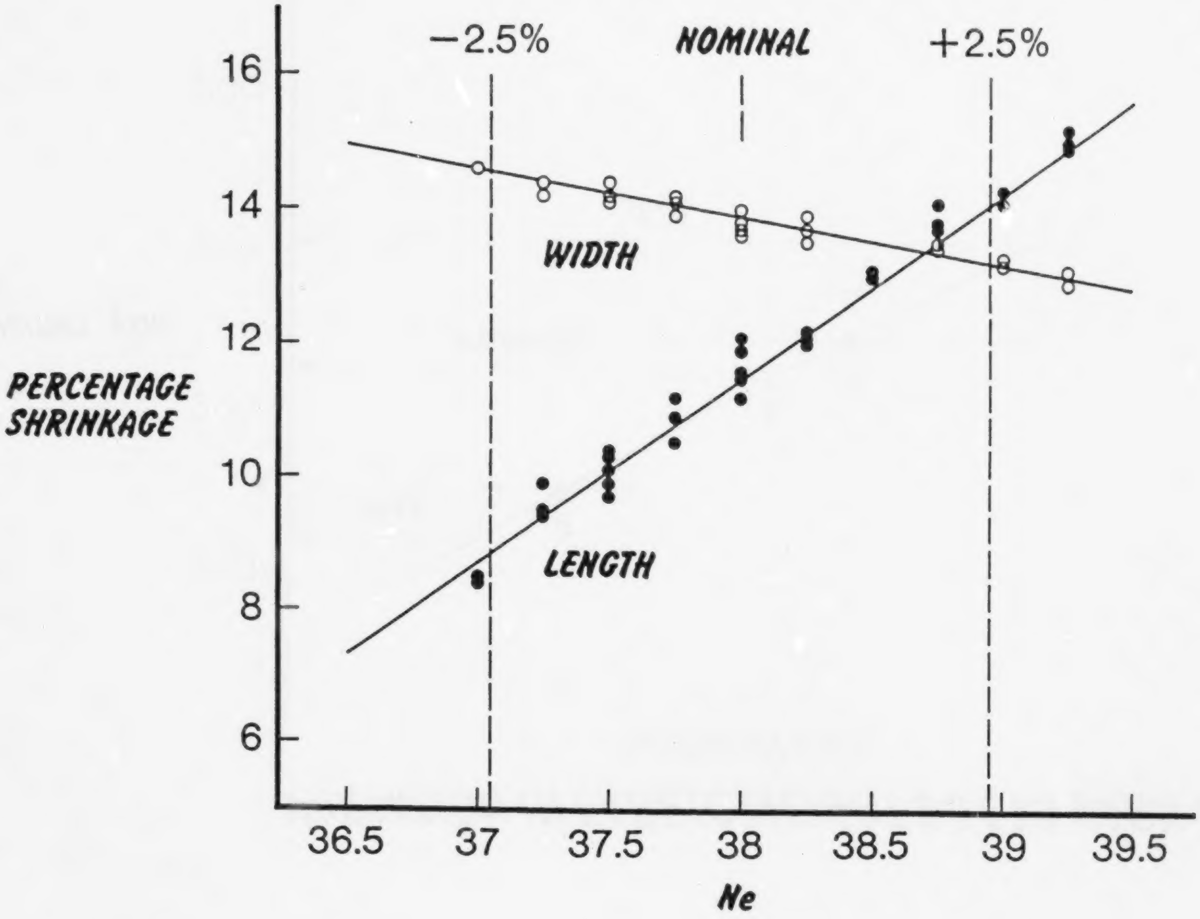
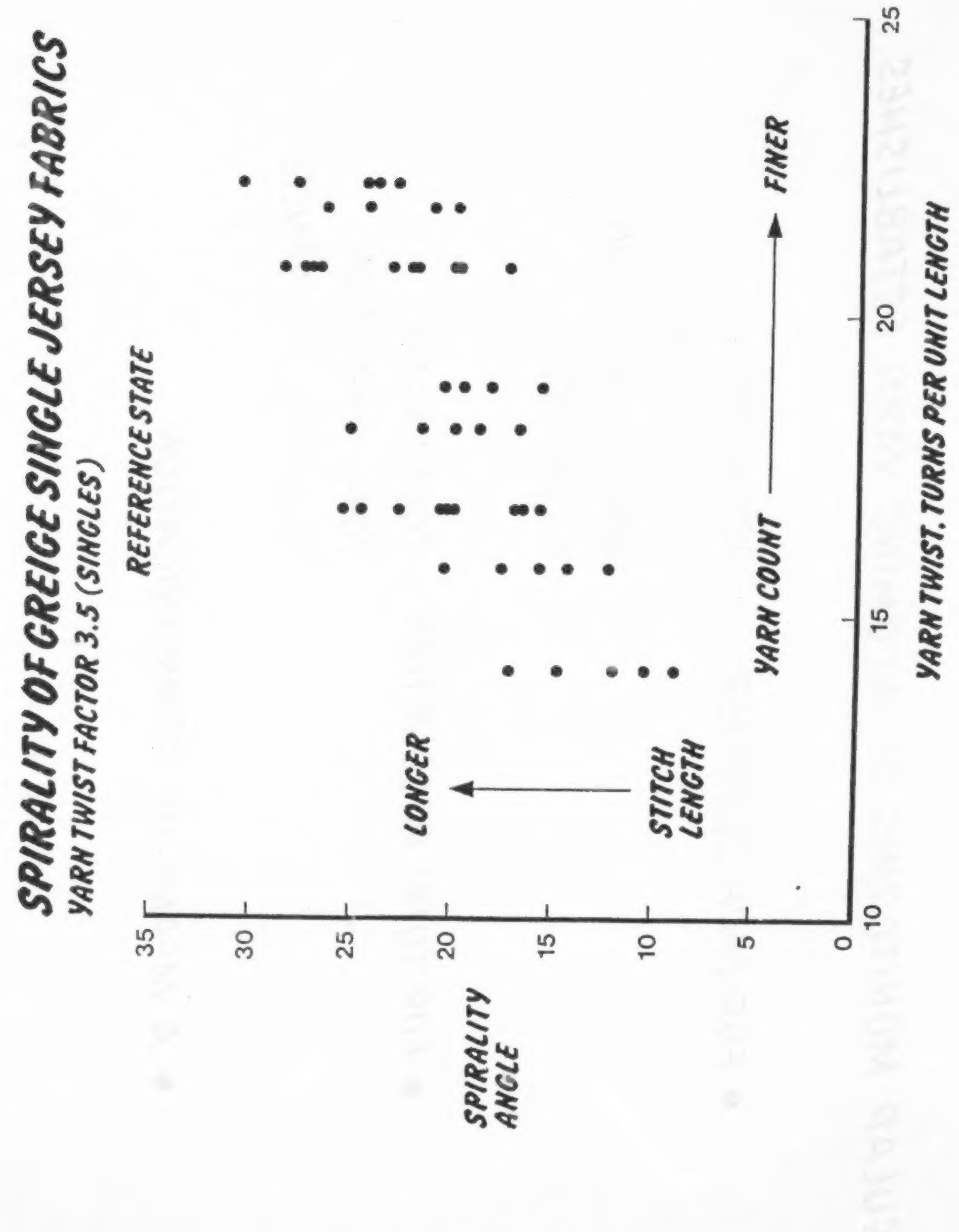


Diagram 19

REGULAR MONITORING OF INCOMING YARN ESTABLISHES..

- FOR EACH SUPPLIER – ACTUAL COUNT
  - CONSISTENCY
  - NORMAL VARIATION
  - TOLERANCES
- FOR TOTAL PRODUCTION – COUNT RANGE
  - TOTAL VARIATION
  - REALISTIC TOLERANCES
- A MEANS OF COMMUNICATION



SPIRALITY OF GREIGE SINGLE JERSEY FABRICS

YARN TWIST FACTOR 3.5 (SINGLES)

REFERENCE STATE

Diagram 21

MAXIMUM UNAVOIDABLE VARIATION IN SHRINKAGE DUE TO KNITTING

---

20 GAUGE INTERLOCK WINCH DYED

YARN.. Nº 1/38 ± 2·5% STITCH LENGTH.. 3·38 mm ± 2·5%

DIMENSIONS	REFERENCE	FINISHED
COURSES/3cm	44·4 – 46·8	40
WALES/3cm	42·9 – 44·4	38

SHRINKAGE	
LENGTH %	9·9 – 14·5
WIDTH %	11·4 – 14·4

Diagram 22

30" 20 GAUGE

	NEEDLES	% DIFFERENCE
THEORETICAL	1886	0
CAMBER CHEMINIT	1872	-0·7
FLONIT H3F	1944	+3·1
MONARCH XL-3S	1860	-1·4

26" 28 GAUGE

	NEEDLES	% DIFFERENCE
THEORETICAL	2304	0
CAMBER CHEMINIT	2304	0
FLONIT	2280	-1·0
MONARCH RX-JS2	2256	-2·1
XL-36	2232	-3·1

Diagram 23

	DIAMETER	GAUGE	NEEDLES	% DIFFERENCE
INTERLOCK	20	20	1260	0
	20	18	1128	-10·5
RIB	14	14	612	0
	14	15	660	+7·8

DISCUSSION

MS J. C. STEVENS' PAPER

A questioner asked the speaker to elaborate on the effect of variations in yarn friction and also of yarn hairiness on the finished article. The speaker could not quantify the specific effect of different friction levels on dimensional properties but said that from a knitting efficiency viewpoint, yarn friction - against steel - had to be kept to a low level and this was achieved normally by waxing the yarn prior to knitting. Various instruments were available for reliably checking yarn friction; one was produced by Shirley Developments and could be inspected in IIC's laboratory.

It was desirable to test samples from each production lot received and one would expect the coefficient of friction to be less than 0.2 for efficient knitting. Normally, good hosiery yarns would have coefficient in the range 0.1 to 0.15, alleviating most of the problems caused by the build-up of excessive tension in the knitting area - yarn breakage and holes, etc. Friction had an important influence on fabric quality but little effect on fabric dimensions when positive feed was used.

Hairiness had not been considered in the STARFISH work because the yarns used so far had been limited to good quality combed counts. Test methods did exist to measure hairiness but combed yarns were obviously less hairy than carded yarns because more of the short fibres had been removed during processing. Certainly hairiness could become a problem during finishing since dyeing and finishing machinery could ruffle up the fabric surface.

A supplementary comment at this point from another speaker expressed the view that once yarn was waxed the hairiness level tended to even out and there was really no problem.

The original questioner wanted to know whether it would be necessary to singe or not and it was suggested that he should probably do so for the very highest quality of knitgoods.

The speaker agreed that differences in needle size and needle type would affect one's ability to knit particular counts or particular tightnesses. On some machines it was possible to knit tighter and finer, or slacker and coarser, than on other machines - the range had to be established individually for each machine.

On the question of spirality the speaker thought the number of feeders had a comparatively small influence compared with the influence of the yarn itself. There was often confusion with pattern spirality - a different phenomenon where the pattern itself would drop down the machine due to the number of feeders. There was some discussion about the connection between spirality and the relative immediacy of use of yarn from a spinner. One delegate said that fresh yarn gave higher spirality. The speaker could not confirm this since the yarns used in all IIC work were at least several weeks old, although another IIC voice added that spirality did go down a little with age but very slowly. The use of steaming was rejected as a solution because it did not appear to have a permanent effect. Dyed yarns tended to show less twist liveliness than the equivalent grey yarn because they had been relaxed during the wet treatment, while open end yarns were more lively and tended to generate more spirality because of their higher level of twist.

Another questioner referred to the fact that the speaker had been dealing principally with standard fabrics of rib construction and gauges of 20, 18, etc. As a knitter he did not have great problems with such fabrics because he had so much experience of them; what worried him was fashion which changed perhaps three, four, eight, maybe even ten times a year. So long as the public demanded fashion garments from cotton, then the knitter had to make them - fleecy fabrics, open fabrics, etc. It was impossible to get the finish and fabric expected by the consumer; they wanted the same shrinkage on an open fabric as on rib.

The speaker agreed with his comments but reminded him that the purpose of IIC's work was to establish certain ground rules for standard fabrics because they still represented bulk useage. It was hoped to extend the work into some of the more fashion-oriented fabrics; but there had not been time or money to expand the data collected thus far into these areas. However, the principles under discussion (i.e. defining shrinkage and setting finishing targets in terms of reference dimensions) could be used to give guidance on finishing procedures for any fabric in order to achieve the required dimensional properties required by the customer.

With fashion fabrics one would also consider more carefully the washing instructions recommended. Standard underwear, outerwear and T-shirt types of fabric would be expected to withstand a degree of hard treatment in laundering. Customers liked to be able to tumble dry, but with the new ranges of knitwear which, for example, imitated lambswool, one did not expect to be able to tumble dry lambswool so why should one expect to tumble dry a cotton equivalent?

Asked to identify the various methods used for measuring course length, the speaker said she had referred to instruments that were available on the market. All types of instrument appeared to give reproducible results but different types gave slightly different readings of stitch length. The choice of instrument was therefore not important but each instrument bought had to be calibrated against laboratory measurements on yarn taken from the grey fabric. For this purpose, IIC used a Shirley Crimp Tester and had found that it measured stitch length very accurately; more accurately in fact than the Hatra Course Length Tester. The problem with the latter was that of unravelling the yarn in the first place; variability was introduced because the tension on the yarn could not be controlled.

Finally, the speaker stated that standard domestic washing machines were used in the IIC laboratories but the effect of using different washing machine types had not been examined. Where tumble drying followed washing, the precise conditions of washing were probably less critical. One could discern a difference in behaviour between fabrics - some would shrink more in washing and less in tumble drying and some less in washing and more in tumble drying. A small garment wear trial had shown that the course and wale level found in the reference state of the finished fabric would be achieved in the garment, even after wearing, if tumble drying were included at some stage in laundering.

SETTING THE FINISHING TARGETS

Mr. P. F. Greenwood
International Institute for Cotton

Why do we need specifications for finished cotton knitted fabrics? The answer, essentially, is to provide targets for the finisher and so to assist him to produce goods of consistent quality.

Maintenance of consistent quality in the finished fabric is impossible without control in the knitting operation. This may seem to be obvious but nevertheless is very often forgotten. If no adequate specification exists for the grey fabric, or if it is not adhered to, there will be little purpose in producing one for the finished fabric because the finisher will not be able to meet it.

If this has not already become apparent from earlier presentations, I hope this paper will throw a little more light on the matter.

What should we include in a specification for cotton knitgoods? First, it must contain certain information provided by the knitter, which we have seen already (Diagram 1).

The finisher will be expected to supply his customer, at least, with fabric of consistent width, weight and dimensional stability (Diagram 2).

This paper will concentrate on the development of specifications for these three parameters, but a complete description of a knitted cotton fabric in the dyed and finished state should make reference to many other properties, for example:-

- colour (with acceptable tolerances)
- colour fastness to appropriate agencies
- appearance
- bursting strength
- stretch and recovery
- sewability

Although the main objective of our own investigations has been to obtain a better understanding of the dimensional behaviour of the knitted cotton structure, a considerable amount of information on other properties has been generated and is being analysed for presentation at a later date. Some of these properties are difficult to quantify, but all are of importance in judging the acceptability of the fabric, and therefore should be specified as far as possible on the basis of previous experience.

The parameters which have been shown in the first two slides are, in fact, sufficient to determine and fix several other fabric properties, using simple mathematics.

WIDTH

The relationship between width, needles in the machine and wale density has already been mentioned today.

Diagram 3

When a specification sets down requirements for width of the finished fabric, knitted on a machine with a specified number of needles, this means that the wale density has also been specified by implication. Sometimes all three parameters appear on a specification, and occasionally the internal agreement between them, using these equations, leaves something to be desired. This makes life more difficult for the finisher than necessary because, of course, if there is contradiction in the specification, he will not be able to achieve all the requirements.

WEIGHT

Fabric weight also is related to other fabric properties as shown in Diagram 4.

DIMENSIONAL STABILITY

What does the customer mean by this? Briefly, she means that if a garment fits comfortably when it is first put on, it will continue to fit comfortably after repeated laundering and wear cycles throughout its expected life span.

Ideally, we would test this by repeated washing and wearing in garment form, but the finisher does not have garments available to him and he would have no time to test them in this way if he had. He must test fabric and, therefore, is limited to washing without wearing. Attempts have been made to simulate wearing conditions by including a re-stretching operation after a washing-drying test cycle, but it is very difficult to carry this out in a reproducible way. In our own research studies, as you have already learned, we decided to use a five-cycle wash and tumble dry test.

Diagram 5

It is not suggested that such a method should become generally adopted as a routine test for quality assessment. Certainly, it is too time-consuming for routine quality control purposes, and a compromise is therefore desirable. However, several points should be considered when setting up a quality control test procedure for dimensional stability. First we have found that several replications - at least three - should be carried out on each processing run tested; and secondly, the drying route has a marked effect on the results obtained. Flat drying and line drying result in less shrinkage compared with tumble drying; we attribute this to the mechanical action of the tumble dryer.

All three drying methods could be regarded as valid in different circumstances; it is up to the finisher and his client to agree on a method appropriate to the market which is being supplied and which will give sufficiently reproducible results.

Having defined the test method it follows that we have also defined the Reference State as the structure which the fabric assumes after it has been subjected to the chosen testing procedure.

THE IMPORTANCE OF THE REFERENCE STATE

The value of the Reference State is that it provides a reference point from which we can find our way to set down targets for the finisher. From the wale density in the Reference State, the width, also in the Reference State, of fabric knitted on a given machine can be calculated; from that, one can then calculate the residual width shrinkage corresponding to any finished width or wale density, or conversely the width to which the fabric should be finished to achieve a required level of widthway stability.

Diagram 6

The wale density, width and residual width shrinkage of the finished fabric are thus not only interdependent, but also depend on the factors already mentioned which control the Reference State. For fabric from a given knitting machine, with a given number of needles, a specification which defines two of these requirements automatically defines the third. If the specification also sets down the parameters already mentioned, which control the Reference State, one requirement is sufficient to define the other two.

In the same way that width shrinkage is related to both the finished width and the width in the Reference State, the total area shrinkage (combining length and width dimensional change) is related to the finished fabric weight and the weight in the Reference State. From the equations already given, if the weight is that of the fabric in the Reference State, one can calculate the area shrinkage corresponding to any other state.

Diagram 7

Thus, a specification in which the finished weight is defined also defines the area shrinkage, and vice versa; this relationship can then be calculated, provided the Reference State of the fabric is known.

ANOMALIES

Before going further, it must be said that we have found, in our studies, two groups of fabric to which this mathematical treatment cannot be applied with certainty. These are:-

1. Fabrics which show variable wale density
2. Fabrics which exhibit spirality

Variable wale density often shows up in open-width mercerised fabrics, but appears not to be a serious problem in other cases.

The second group, those which exhibit spirality, includes most single jersey fabrics knitted from singles yarns. The difficulty arises because any method which induces relaxation in these structures also causes them to twist, due to residual torsional forces in the spun yarn. The wales and courses are then no longer at right angles, and do not correspond with the normal length and width directions of the fabric.

The problem is therefore one of fabric design; the effect is an integral part of the Reference State, and the ability of the finisher to correct it, without resorting to methods which distort the structure beyond acceptable levels of stability, is very limited. In any case, mechanical methods of straightening the fabric do not alter the Reference State, and the spirality returns after laundering, so that a garment which exhibits the fault may eventually become unsightly or even unwearable.

As our conference is entitled "The Production of High Quality Cotton Knitgoods" such fabrics really have no place in it, but some treatments can have an ameliorating effect. Piece mercerisation can produce an improvement; so can crosslinking which will be described in the next paper. The point to be made here is that a specification for such a fabric should include a reference to spirality. This can be described in various ways; we usually refer to the angle of spirality as the angle between the wales and the perpendicular to the line of courses. An acceptable limit for angle of spirality is probably about five degrees in the Reference State.

THE EFFECTS OF PROCESSING ON THE REFERENCE STATE

The dimensions of the Reference State depend upon:

- the method of relaxation
- the knitted fabric structure
- the finishing process

(Diagram 8)

The importance of the first two has been explained in earlier papers today, and it has been shown that finished fabric does not exhibit the same Reference State as the original greige fabric.

It has already been shown that changes in the knitted stitch length and grey yarn count affect the course and wale densities of the grey fabric in the relaxed, or Reference, state. Changes in yarn count and stitch length can also take place as a result of the finishing treatment.

Stitch length, for instance, can be expected to become shorter as a result of yarn shrinkage and we can see (Diagram 9) some yarn shrinkages which we have encountered in our commercial-scale processing trials.

If yarn shrinkage were the only factor to be considered, one would suspect yarn count changes resulting from wet processing to be similar to the observed stitch length changes. Yarn shrinkage however is only one of the mechanisms which can affect the count, others being:

- fibre loss in processing
- non-fibrous loss

both of which reduce the tex (finer count), and

- added weight (dyestuff, lubricant, resin, etc)

which will increase the tex (coarser count). Some trends which we have encountered are shown here (Diagram 10).

Now, can we use these observed effects to calculate the finished Reference State dimensions simply from our knowledge of the grey fabric behaviour?

Unfortunately, it is not as simple as that, as we can see by looking at the data given in Diagram 11, from one of our full scale finishing trials. The figures are for a dyed 14 gauge 1 x 1 rib fabric, typical of many which we have studied. The yarn has shrunk slightly in processing so we might have expected that the fabric, in its Reference State, would also be more compact, with tighter course and wale densities. In fact the reverse has occurred, in both directions, and the fabric is much more open than would have been calculated using the classical theory, which has already been outlined, based on grey fabric behaviour. There is thus a third influence which affects the behaviour of the finished fabric; its nature is indicated by the difference between the observed and calculated values.

Diagram 12
The nature of this third influence is not yet understood; it may be a kind of setting effect.

This diagram introduces the concept of the "F" or "finishing" factor, which describes the change in a Reference State dimension produced as a result of a particular finishing treatment, and is derived by comparing corresponding data for greige and finished Reference States.

F-factors may be calculated for course and wale densities, weight and width; but for the finisher the most important of these are the factors for width and course density. These can be used to calculate his targets.

Some examples to show this will be given in a moment, but first let us look at Diagram 13.

Some F-factors which we have found in our trials in single jersey. From these figures, we can see that winch dyed fabric has a Reference State which is slightly wider and considerably longer than the corresponding greige fabric, whereas tubular mercerised fabric is much narrower.

Comparing winch dyed fabric with the same fabric dyed in the Thies Roto-Stream machine, we see that the fabric dyed in the Roto-Stream must be finished about 2% wider to exhibit the same residual width shrinkage characteristics. Put another way, if both are finished to the same width, the winch dyed fabric will shrink 2% more than the other.

Each machine and each process makes its own contribution to the F-factors, and a good finisher must establish the factors corresponding to his own production, and use them to agree working specifications for the fabrics which he processes.

Although it is unlikely that all fabrics processed through a particular route will behave exactly the same way; that is, have exactly the same finishing factors, we have found that in practice they do behave rather similarly. Nevertheless, the finisher who wants to retain control of dimensional stability would be well advised to examine carefully the behaviour of each new quality which he is asked to process.

The influence of any alteration in an established processing route, for instance the introduction of a new dyeing machine, should also be carefully monitored.

In our trials, even the same machine used in different dyehouses has been found to give slightly different results.

Diagram 14

Here, fabric processed to a given width at dyehouse 3 would have 3% more shrinkage than the same fabric processed at dyehouse 1, using the same dyeing machine.

USING THE REFERENCE STATE

The determination of the Reference State, then, is an essential first step in the formulation of a reliable specification for a given fabric processed by a given dyeing and finishing route. Let us examine various ways in which this concept can be used in a finishing works.

First, taking perhaps standard, well-established fabric constructions and finishing routes, he can compare Reference States in the greige and finished states and from the results calculate F-factors to indicate the effect of his finishing treatment.

Diagram 15

An example is shown here of a 20 gauge interlock fabric, jet dyed. From the observed changes in the Reference State resulting from finishing F-factors have been calculated for course density and width.

In addition, targets for finished coursedensity and width have been calculated to give 10% residual shrinkage in length and width directions.

Diagram 16 shows how the information obtained from the behaviour of the standard fabric can be applied to a slightly different construction to establish new finishing targets. The knitter has increased the stitch length of the greige fabric from 0.340 to 0.350 cms. Measurements of the new fabric in the Reference State show that it has 48 courses per 3cm and a tubular width of 51.7 cm. Application of the F-factor allows us to predict that the Reference State of the finished fabric will have 44.7 courses per 3cm and a width of 53.3 cm. Aiming for 10% residual shrinkage in length and width, as before, gives targets for finishing the new fabric of 40.2 courses per 3cm and a finished width of 59.2 cm.

A tentative specification for finishing the new fabric has thus been set down before any fabric has been processed, using only our knowledge of the greige Reference State and our experience of the behaviour of similar fabrics.

The F-factors may not be exactly the same for the new fabric as for the old, but as the structural change was a minor one, they will not be very different, and after a few finishing runs have been carried out, and the behaviour of the new fabric recorded, the new factors can be corrected.

The technique, then, gives the finisher a realistic set of targets for a new fabric.

Diagram 17 shows how the concept can be applied to the introduction of a new process into a finishing works, taking as our example, the process of piece-mercerisation.

Machinery for the tubular mercerisation of knitted cotton piecegoods was introduced to the industry less than ten years ago, yet it is fast becoming an indispensable addition to the knitgoods dyehouse facilities. Although the technique has many advantages, the fabric is completely altered in structure. The finisher is thus presented with the problem of finishing the mercerised fabric to a satisfactory state of dimensional stability.

By first establishing his Reference State for the mercerised and dyed fabric, he can calculate as already shown the correct finishing width and course density for his targets or desired levels of dimensional stability.

Diagram 17

For example, a single jersey fabric knitted from Ne 56/2 yarn on a 1920 needle machine to a stitch length of 0.321 cm was mercerised on an Omez tubular mercerising range, followed by dyeing. The course and wale densities of the finished fabric in the Reference State were 45 and 50 respectively per 3cm. How should the fabric be finished to have a residual shrinkage of 10% in both length and width, and what will be the weight per square metre of the finished fabric?

The width in the Reference State can be calculated from the wale density to be 57.6 cm (tubular). For 10% width shrinkage the finished width is then calculated to be 64 cm, while for 10% residual length shrinkage the course density in the finished fabric should be 45 x 0.9 = 40.5 per 3cm.

If we assume that the stitch length has been reduced by 7%, and the yarn count has increased by 2% for whites and 7% for deep-dyed in processing, as we saw from earlier slides, then the finished weights can be calculated from the equation given earlier, and are found to be 129.9 and 136.3 g/m^2 respectively.

We now have a specification for the finished fabric:-
Diagram 18

Width (tubular)	64 cm
Course per 3cm	40.5
Weight (white)	130g/m^2
Weight (deep dyed)	136g/m^2
Shrinkage - length	10%
- width	10%

which is self-consistent. The shrinkage targets, of course, should be somewhat less than the maximum allowable, probably by about 2%, to take account of the natural variation in both fabric construction and finishing conditions.

So far we have considered only the Reference State of the fabric after finishing, but we can go a step further if we obtain corresponding data for the original greige fabric.

Diagram 19
For this particular fabric it was found that the course and wale densities were 53 and 40 respectively. The tubular width of the greige fabric in the Reference State, calculated from the wale density, would be 72 cm.

Thus, for this fabric processed by this route the finishing factor for width calculation is 57.6/72 = 0.8, and the finishing factor for course density is 45/53 = 0.85.

After the behaviour of several fabrics has been observed over a number of processing runs, the magnitudes of these factors can be calculated with increased precision.

TOLERANCES

It would be rather unreasonable to expect a finisher to adhere rigidly to the targets laid down in a specification even if there were no internal inconsistencies such as have already been discussed. Some variability must be allowed, and these will naturally form part of the specification.

In an earlier paper, it was suggested that ±2.5% might represent reasonable limits for yarn count and stitch length variations, perhaps rather more for yarn count and perhaps less for stitch length. It can be shown that these will produce a variation in greige fabric weight of ±3.5% in the Reference State. This can also be held to represent the best possible tolerance for finished fabric weight, only attainable when course and wale density targets are achieved exactly, and when yarn count changes due to dyeing and finishing are constant.

A more realistic tolerance for finished fabric weight would perhaps be nearer ±5%.

Variations are also inevitable, in the real world, in width and course density and the specification for that mercerised single jersey fabric might be rewritten in a more practical form as:in Diagram 20:

Width (tubular)	64 ± 1 cm
Courses per 3cm	40.5 ± 1
Weight (white)	130 ± 7g/m^2
Weight (deep dyed)	136 ± 7g/m^2
Shrinkage - length,	not more than 12%
- width,	not more than 12%

VALIDATION

At this stage, our specification is still based to a large extent on theory and guesswork, and must be validated by extensive sampling from production runs. We may then find that one or more of these targets is difficult to attain. There may be several reasons for this, among them:

- incoming fabric does not correspond to knitted specification
- the factors used are not appropriate for the finishing process

- the fabric structure may be outside the range for which the factors apply
- one or more of the factors used may not be sufficiently accurate
- the shrinkage limit may be unattainable with the finishing machinery available

We shall hear more about this last point in the next paper. With regard to the others, it means going back to check and re-check in systematic investigations with the co-operation of the knitter and the customer. The importance of the links between knitter, finisher and fabric user has been emphasized in previous papers but no apology is made for repeating this point. It is vital for the subject of our conference this week, "The Production of High Quality Cotton Knitgoods".

BASIC KNITTING SPECIFICATION

1. FABRIC TYPE
2. STITCH LENGTH
3. YARN COUNT AND TYPE
4. MACHINE TYPE AND SIZE (NEEDLES)

Diagram 2

BASIC FINISHED FABRIC SPECIFICATION

1. WIDTH – WALE DENSITY
2. LENGTH – COURSE DENSITY
3. WEIGHT – PER UNIT AREA
4. PERFORMANCE – SHRINKAGE

Diagram 3

$$\text{WALES PER CM.} = \frac{\text{NUMBER OF NEEDLES}}{\text{OPEN, UNTRIMMED WIDTH (CM.)}}$$

OR

$$\text{WALES PER CM.} = \frac{\text{NUMBER OF NEEDLES}}{\text{TUBULAR WIDTH (CM.)} \times 2}$$

Diagram 4

$$\text{WEIGHT } (g/m^2) = \frac{S \times \text{yarn count (tex)} \times \text{stitch length (cm)}}{10}$$

OR

$$\text{WEIGHT } (g/m^2) = \frac{S \times \text{stitch length (cm)} \times 59}{\text{yarn count (Ne)}}$$

c = courses per cm.

w = wales per cm.

S (stitch density) = $(c \times w)$ stitches per cm^2.

Diagram 5

TO ACHIEVE THE IIC REFERENCE STATE

1. **WASH** IN AUTOMATIC DOMESTIC WASHING MACHINE AT 60°C
2. **TUMBLE DRY** UNTIL DRY
3. **WET OUT** IN WASHING MACHINE (RINSE CYCLE)
4. **TUMBLE DRY** UNTIL DRY
5. **REPEAT** STEPS 3 AND 4 THREE MORE TIMES
6. **CONDITION**

Diagram 6

CALCULATING A TARGET FOR FINISHED WIDTH

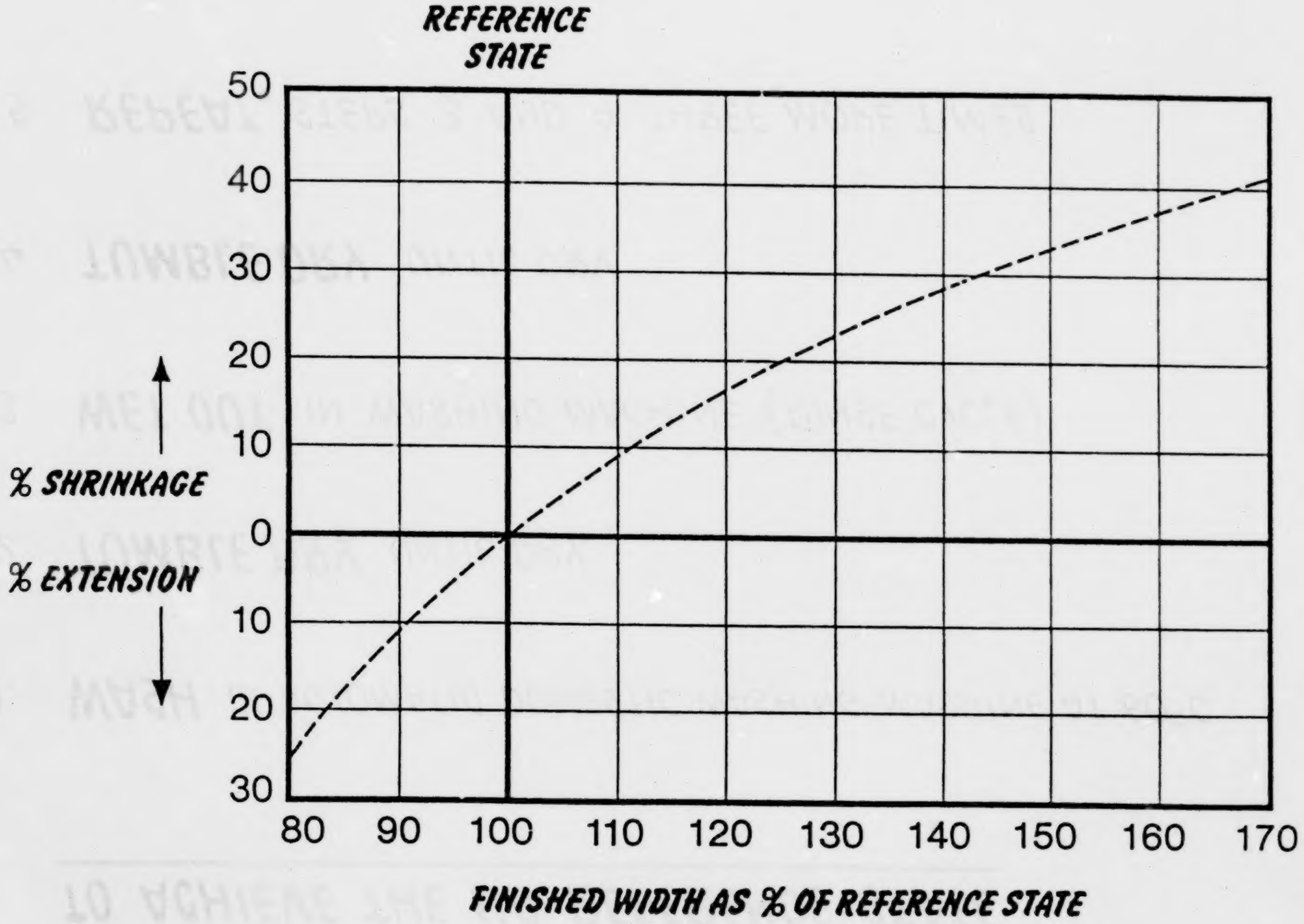


Diagram 7

CALCULATING A TARGET FOR FINISHED WEIGHT

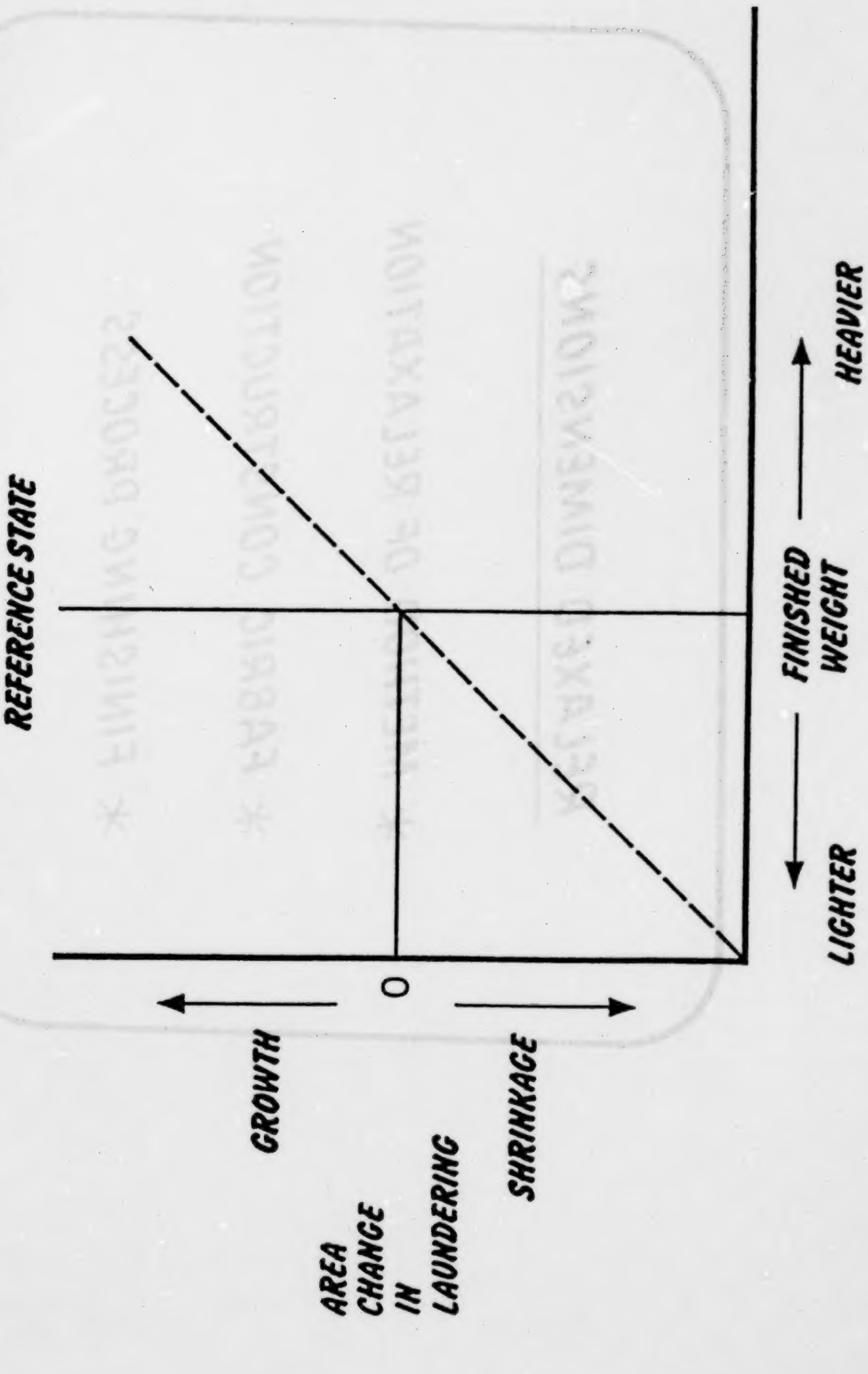

REFERENCE STATE
GROWTH
0
SHRINKAGE
AREA CHANGE IN LAUNDERING
LIGHTER
FINISHED WEIGHT
HEAVIER

Diagram 8

RELAXED DIMENSIONS

* METHOD OF RELAXATION
* FABRIC CONSTRUCTION
* FINISHING PROCESS

Diagram 9

COTTON KNITGOODS

YARN SHRINKAGE IN WET PROCESSING

DYED - NOT MERCERISED	1 - 3%
OPEN-WIDTH MERCERISED	3 - 4%
TUBULAR MERCERISED	6 - 7%

Diagram 10

COTTON KNITGOODS

YARN COUNT (TEX) CHANGES IN WET PROCESSING

	WHITE/PALE	DEEP
NOT MERCERISED	-3%	0
OPEN-WIDTH MERCERISED	-2%	–
TUBULAR MERCERISED	+2%	+7%

Diagram 11

KNITTED COTTON FABRIC

1 × 1 RIB, 14 GAUGE, Ne 30/1 COMBED, STITCH LENGTH 0·285 cm.

	REFERENCE STATE	
	COURSES/3cm	WALES/3cm
GREIGE	56·1	34·2
PREDICTED AFTER DYEING (ASSUMING 2% YARN SHRINKAGE)	57·2	34·9
DYED	52·8	32·6

Diagram 12

FINISHING AND THE REFERENCE STATE

1. CHANGE IN STITCH LENGTH
(YARN SHRINKAGE)

2. CHANGE IN YARN COUNT
(LOSSES IN BLEACHING, ETC.,
GAINS IN DYEING, ETC.)

3. ? ? ?

= 'FINISHING FACTOR'

Diagram 13

FINISHED WIDTH AND COURSE DENSITY FROM GREIGE REFERENCE STATE

24 & 28 GAUGE SINGLE JERSEY

PROCESS	WIDTH FACTOR	COURSE DENSITY FACTOR
DYED IN WINCH	1·02	0·94
DYED IN THIES ROTOSTREAM	1·04	0·95
MERCERISED (TUBULAR)	0·83	0·85
MERCERISED (OPEN-WIDTH)	0·98	0·94

Diagram 14

FINISHING FACTORS

FABRIC : SINGLE JERSEY, 24 & 28 GAUGE
PROCESS: DYEING IN THIES ROTOSTREAM

	WIDTH FACTOR	COURSE DENSITY FACTOR
DYEHOUSE 1	1·04	0·95
DYEHOUSE 2	1·02	0·95
DYEHOUSE 3	1·01	0·94

Diagram 15

INTERLOCK SINGLE JERSEY

Fabric Type	Interlock, 20 gauge
No. of Needles	1500
Yarn	Ne 38/1, combed
Stitch length	0.340 cm

- - - - - -

Reference State

	Greige	Dyed
Courses per 3 cm	49.5	45.9
Tubular Width (cm)	51.1	52.5

- - - - - -

Finishing Factors

for Course Density $\frac{45.9}{49.5} = \underline{0.93}$

for Width $\frac{52.5}{51.1} = \underline{1.03}$

- - - - - -

Targets for 10% Shrinkage

Courses per 3 cm $45.9 \times 0.9 = 41.3$

Tubular Width (cm) $52.5 \div 0.9 = 58.3$

Diagram 16

Fabric Type	Interlock, 20 gauge
No. of Needles	1500
Yarn	Ne 30/1, combed
Stitch Length	0.350 cm

- - - - - -

Reference State

	Greige	Dyed
Courses per 3 cm	48.0	?
Tubular Width (cm)	51.7	?

- - - - - -

Calculate using FINISHING FACTORS

Courses per 3 cm	48.0 x 0.93 = 44.7
Tubular Width (cm)	51.7 x 1.03 = 53.3

- - - - - -

Targets for 10% shrinkage

Courses per 3 cm	44.7 x 0.9 = 40.2
Tubular Width (cm)	53.3 ÷ 0.9 = 59.2

Diagram 17

Fabric Type	Single Jersey, 24 gauge
No. of Needles	1920
Yarn	Ne 56/2
Stitch Length	0.321 cm

Processing-Tubular mercerised, dyed

- - - - - -

Reference State

	Mercerised and Dyed
Courses per 3 cm	45.0
Wales per 3 cm	50.0

Calculated tubular width in the Reference State

$$\frac{1920}{2} \div \frac{50}{3} = 57.6$$

- - - - - -

Targets for 10% shrinkage

Courses per 3 cm	$45.0 \times 0.9 = 40.5$
Tubular Widtn (cm)	$57.6 \div 0.9 = 64.0$

Diagram 18

SPECIFICATION FOR 24 GAUGE SINGLE JERSEY, TUBULAR MERCERISED

- - - - - -

Knitting

No. of Needles	1920
Yarn	Ne 56/2
Stitch Length	0.321 cm

- - - - - -

Finished Fabric

Tubular Width	64 cm
Courses per 3 cm	40.5
Weight - white	130 g/m^2
- deep dyed	136 g/m^2
Shrinkage	
- length	10%
- width	10%

- - - - - -

Diagram 19

Fabric Type	Single Jersey, 24 gauge
No. of Needles	1920
Yarn	Ne 56/2
Stitch Length	0.321 cm

- - - - - -

Reference State

	Greige	Finished
Courses per 3 cm	53.0	45.0
Wales per 3 cm	40.0	50.0
Tubular width (cm)	72.0	57.6

Diagram 19 cont'd

Finishing Factors

for Course Density $\frac{45.0}{53.0} = 0.85$

for Width $\frac{57.6}{72.0} = 0.8$

_ _ _ _ _ _

Diagram 20

SPECIFICATION FOR 24 GAUGE SINGLE JERSEY, TUBULAR MERCERISED

_ _ _ _ _ _

Knitting

No. of Needles	1920
Yarn	Ne 56/2 ± 2.5%
Stitch Length	0.321 cm ± 2.5%

_ _ _ _ _ _

Finished Fabric

Tubular Width	64 ± 1 cm
Courses per 3 cm	40.5 ± 1
Weight - white	130 ± 7 g/m^2
- deep dyed	136 ± 7 g/m^2
Shrinkage - length	not more than 12%
- width	not more than 12%

FINISHING TO SPECIFICATION - ACHIEVING THE TARGETS IN PRACTICE

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INTRODUCTION

In the previous paper my colleague has highlighted the key points which have to be considered when setting finishing targets and showed why it is sometimes necessary to make specific allowances for certain processing routes when establishing specifications for particular end-uses.

Jill Stevens highlighted the importance of knitting within specification and outlined the problems which can be created for the finisher if knitting is not kept under strict control.

By and large, any knitter with reasonably modern knitting machines who ensures his yarn supply is consistent and who takes the necessary measures as outlined by Miss Stevens should not have too much difficulty in achieving a realistic knitting specification.

Invariably to maintain a degree of flexibility into their operation, major customers will commission a number of knitters and a number of finishers to meet their requirements. Even if it is assumed that the finishers are all receiving more or less consistent starting material which is within the customer's knitting specification, they can still face a number of problems which can make it difficult for some of them to achieve the finished specification.

These difficulties can be due to a single factor or a combination of factors, the main ones being:

1. That the individual processing steps involved in the operations of dyeing and finishing can all have an effect on the fabric structure. In many cases this is only a temporary effect but in some cases it can be a permanent effect and the reference state of the fabric will be altered as was highlighted in the previous paper. In either case the ability of the finisher to hit the customers specification can be influenced to a greater or lesser degree.

2. Allied to this is the fact that many specifications are in fact established in the first instance on the performance or ability of a single finisher and therefore probably on a particular processing sequence.

   Since it is unlikely that every finisher commissioned to finish that quality will have an identical combination of processing machines or methods, this can lead to difficulties for some of the finishers in attaining specification.

3. Perhaps the main factor why some finishers have difficulty in achieving certain specifications is simply that their plant is unsuitable. Many companies are attempting to process knitted cotton outerwear fabrics on equipment which was installed for processing synthetic fabrics.

As an introduction I think it would serve a useful purpose to outline the situation as it was in the early 70's when we first began to get involved in cotton knitgoods finishing in terms of methods and machinery and to highlight the changes which have occurred over the past decade to enable the finishing of cotton outerwear to be carried out to the standards essential for the achievement of current day specifications.

STATE OF THE ART IN THE EARLY 1970's

In the early 70's most outerwear fabrics produced by knitting rather than weaving were made predominantly from texturised polyester yarns.

Dyeing was carried out on high temperature jet dyeing machines and finishing was invariably carried out in open-width. The inherent property of thermoplasticity meant that fabrics could be heat set with the result that fabric shrinkage was not a major problem. Considerable quantities of circular knitted cotton fabric were also being processed, but this was almost entirely for the underwear market. Most of this production was being carried out on purpose-built high production plants based on kiers, J-boxes or conveyor steamers, but some was also being processed on a smaller scale using winches.

Although shrinkage was not a major problem with fabrics made from thermoplastic fibres, it was a problem with fabrics made from cotton, even though test methods at this time did not stipulate tumble drying and the incidence of tumble dryers in the home was relatively low.

To allow for the shrinkage of cotton fabrics, underwear garments and vests in particular, were made generously long so that even though the fabric would probably shrink during laundering, the garment would still be long enough for a comfortable fit.

To some extent, consumers expected cotton underwear to shrink and frequently bought a size larger to allow for shrinkage.

Width shrinkage though present was not a problem since a degree of width shrinkage was considered advantageous to ensure a close fit. To help to reduce fabric length shrinkage prior to garment manufacture the major underwear processors installed compressive shrinking machines or compactors into their processing lines. The Hunt and Moscrop "Bestan" machine and the Tubetex "Compactor" were used almost as a matter of course on the higher quality underwear fabrics.

When processing knitted cotton fabrics for outerwear, however, the finisher was faced with a number of problems arising mainly from the fact that the requirements for outerwear are different from those for underwear. In particular fabrics for outerwear frequently need to be dyed. Also the practice of oversizing of garments to allow for fabric shrinkage is not generally possible due to styling considerations and therefore low residual fabric shrinkage becomes far more important. Whilst the compactor gives an acceptable finish on underwear fabrics it is rather unacceptable for outerwear due in the main to the fact that the fabric surface appearance can be affected to an unacceptable degree. The resultant surface polishing can temporarily alter the apparent depth of shade of dyed fabrics which can lead to complaints or returns for off-shade deliveries.

Even with these disadvantages considerable quantities of knitted cotton outerwear fabrics have been, and still are, being compacted throughout the world.

For the higher quality end of the outerwear market, however, the effect of compaction on the fabric surface appearance was becoming increasingly unacceptable and finishers were increasingly under pressure to avoid the use of compaction and to find alternative methods of reducing potential length shrinkage.

Because of the implications to the growth of the use of cotton yarns in knitted outerwear, a decision was taken that IIC should undertake an investigation into the production of outerwear fabrics to determine whether an alternative approach to compaction could be found.

IIC's EARLY ATTEMPTS AT A SOLUTION

The basis of our early work to try to find a solution was the knowledge that the knitted stitch length has a major influence on the shrinkage of greige state fabric. We were interested to determine whether any steps taken at the knitting stage could in fact be of any assistance to the finisher in helping him to produce fabrics with lower residual shrinkage values without having to use a compactor.

However, as we have already seen, changing stitch length will alter other properties one of which is weight. Therefore, if the stitch length is to be changed it will probably be necessary to change to a different count of yarn if a particular target finished weight is required.

To investigate this inter-relationship between yarn count and stitch length on final fabric properties and in particular on residual length shrinkage, sets of 14 gauge 1 x 1 rib and 20 gauge interlock were produced in a range of yarn counts and stitch lengths. These sets were processed through a number of different routes in mills in the UK and in Europe and after finishing were subjected to a comprehensive testing programme.

Since a particular combination of yarn count and stitch length produces a more or less unique fabric, individual finishing targets had to be calculated for each piece of fabric using the procedures already described in the previous paper. Using these individual targets full pieces of each fabric variant were processed through a number of routes.

Throughout the processing sequences, fabric width and relative length were closely monitored at all stages of processing. Relative length can be monitored by determining the linear density of the rows of stitches or courses using a counting glass. This technique gives an immediate indication at any stage of processing of just how near the fabric is to final finished specification. Diagram 1 shows an example of how this information can be used to assess the suitability or otherwise of a particular processing sequence. This example monitors the structure of a particular 14 gauge 1 x 1 rib fabric which was jet dyed, centrifuged, dried and finally calendered.

The target dimensions for this particular rib quality were 49 courses/3cm at a width of 49 cms. In the greige state the fabric already had 49 courses/3 cm but during the operations of dyeing, hydroextracting and drying some length extension occurred which is indicated by the loss of 3 courses/3 cm.

The fabric was calendered slightly wider than target width to allow for some creepback and a small amount of this length extension was recovered. After a period of storage, the fabric crept back to target width but the fabric length remained constant. It is clear that with this processing route that we were unable to meet specification in terms of the number of courses/3 cm and this would be apparent as excess length shrinkage.

This was to be one of the major findings of our initial work and applied to a wide range of processing routes to a greater or lesser degree. One fact which did emerge was that the shortfall in attaining target courses was always smaller in the case of a tightly knitted fabric than in the case of a slacker knitted fabric resulting in lower residual length shrinkage levels.

Although this can be used by a vertical organisation to slightly alleviate the shrinkage problem, it must be remembered that changing fabric tightness has other consequences which must be taken into consideration when setting the finishing targets. For the commission finisher, who has no control over the fabric being sent to him, this is of little consolation however.

It is apparent that once fabric extension has occurred during the wet processing operations there is very little chance of recovering the extension during the subsequent processing operations when using a traditional processing route such as the one described here. Although this processing was carried out a number of years ago it is still typical of what is being carried out in many plants today around the world.

Why therefore are we unable to achieve target?

REASONS FOR FAILURE TO ACHIEVE THE TARGETS

Shrinkage of knitted fabrics has been shown to be attributable to the release of knitting tensions and the realignment of the knitted loops rather than shrinkage of the yarn which is only approximately 1½%. When considering fabric shrinkage it is common to refer only to the changes of fabric dimensions in the length and width directions but in fact the third dimension is also altered. The third dimension which is never measured in commercial practice is fabric thickness.

Diagram 2 shows quite clearly the changes in fabric thickness which can occur during laundering and that the method of drying has an influence on the resultant thickness.

Mechanisms of fabric shrinkage can be rather complex but it has been suggested that there are two components to shrinkage:

- relaxation of strain
- consolidation of the structure

The relative contribution of these two components to the total shrinkage is highly variable and is influenced by, amongst other factors, method of drying. We were therefore interested to learn more about tumble drying to determine what factors or combination of factors give rise to the consolidation in fabric structure which usually occurs.

Samples from a range of cotton knitted fabrics processed in a number of different ways were monitored closely throughout the shrinkage test. Different behaviour patterns were observed but they could generally be placed in one of two categories:

- where a large proportion of the total shrinkage occurs in the washing procedure and the remainder occurs during tumble drying,
- where only a small proportion of the shrinkage occurs in the washing treatment and the majority of the shrinkage occurs during tumble drying.

In the first case one could speculate that fabrics which fall into this category would show very similar shrinkage figures when tested by methods based on line drying and tumble drying.

In the second case where consolidation seems to be the predominant component we would perhaps expect to see larger differences between line drying and tumble drying.

Diagram 3 is an example of a fabric which falls into the second category. The length shrinkage occurring in the wet relaxing treatment amounts to about 6½ percentage points. After tumble drying, this increases to about 14 percentage points.

The interesting feature is that during the removal of most of the moisture, little additional shrinkage occurred even though the fabric was in a state of mechanical agitation. It is only when the fabric moisture content is reduced to below 30% that consolidation begins. What therefore are the inferences to be made from such observations which can be used to assist in designing better processing procedures?

1. Fabric length extension rather than shrinkage can be expected during the dyeing operation.

2. A length reduction of up to 20% must be achieved during subsequent processing operations.

3. Most shrinkage which occurs during drying occurs at moisture contents below 30% and that some mechanical agitation is necessary.

4. An increase in fabric thickness is a consequence of allowing consolidation to occur and therefore operations which reduce fabric thickness are to be avoided where possible.

If fabrics are to be processed so that they exhibit acceptable shrinkage levels, particularly to the tumble dry test, then we believe there are two alternative approaches which offer a solution to the problem (diagram 4).

BASIC APPROACHES TO A SOLUTION

1. Devise better processing methods and equipment which will enable a better interaction between fabric length, width and thickness to be achieved so that these parameters in the delivered fabric are closer to those of the reference state.

2. Alter the reference state of the fabric so that the parameters of length, width and thickness are closer to what can best be achieved in practice on existing equipment.

Although these alternative approaches may enable the excessive shrinkage problem to be reduced or overcome it must be clearly recognised that the properties of the delivered fabric produced by these alternative methods will be very different and as such will require different finishing specifications.

I will now outline examples of these two alternative approaches.

1. BETTER EQUIPMENT AND METHODS

After many hours in a dyeing machine fabrics can be in a state where the length will have to be reduced by as much as 10-20% during subsequent processing if specification is to be met. One method of reducing length is by considerably increasing fabric width. To some extent the width is increased at the final steam calendering stage but the degree to which it can be increased is limited by the need to deliver fabric at a specific width and in practice there is in fact little or no change in length. If the interchange of length and width can be carried out at an earlier stage of processing then a much larger width stretch can be imposed since there still remains the possibility of reducing the width whilst still maintaining the reduced length.

This is the basis of a technique known as wet-stretching or wet spreading. Instead of using the traditional centrifuge to remove excess water, followed by a de-twisting of the fabric rope, these operations are combined into a single continuous operation. (Diagram 5).

The fabric in rope form is first opened out by inflation of the tube with compressed air. It is then passed over a driven expander the width of which is adjustable. Considerable overfeed is applied to the capstan wheels so that the fabric is driven onto the expander at a greater speed than that at which it is removed. By setting the width of the expander to an amount greater than the target finished width of the fabric, an interchange of length for width can be achieved which results in a reduction in length. On leaving the expander the fabric is passed through squeeze rolls to remove excess water.

The machine in diagram 6 is the Calator 'Airtex' which has been available now for a number of years. A number of other machinery builders manufacture units on which wet-spreading can be carried out including Tube-tex, Heliot, Weiss, Pegg-Whiteley, Jawatex.

Diagram 7 shows measurements taken on a 20 gauge Interlock fabric which was wet-stretched on a Calator 'Airtex' machine, following winch processing.

The target finished course level was 41 courses/3 cm but after the dyeing operation it only had 35 courses/3 cm. Thus to hit target we need to reduce fabric length by approximately 17% during subsequent processing.

By stretching the fabric in the width direction whilst applying considerable overfeed in the length direction it was possible to increase the courses by 4 per 3 cm or, in other words, to reduce fabric length by approximately 11%.

To achieve this length reduction, it was necessary to stretch the fabric in width by up to 50% based on the target finished width.

As soon as the constraints of the expander are removed there is an immediate snap back in width but even so, at this stage, the fabric is at a width of 73 cm which is in excess of the target by 17 cms (or 30%).

We need to lose this excess width during the drying operation otherwise the fabric will show excessive width shrinkage and be out of specification in terms of width and weight.

During the drying operation the reduction in length achieved by wet-stretching must be maintained. There are many different types of drying machine available for circular knitgoods and most finishers have a particular preference. One common type of knitgoods dryer which is manufactured by a number of machinery builders and is popular because of its high drying efficiency is a type commonly referred to as a suction drum dryer. With this machine the fabric is held in intimate contact with one or more stainless steel perforated drums by the passage of air which is drawn through the fabric into the drums. This mode of action does not allow the contraction in fabric width to occur which is required following wet-stretching and, therefore, these dryers are somewhat unsuitable, if wet-stretching is being carried out. They can be used as a predryer and I would like to return to this point in a few moments.

Another drying machine commonly used throughout the world is a Tubetex Super Relax-Jet and last year we were able to carry out a wet-stretching trial using the Tubetex dryer. The wet-stretching operation was carried out on a Tubetex Tri-Pad. This is a padder which is equipped with a driven expander and has over-feeding facilities. This particular trial was carried out on a 14 gauge 1 x 1 rib fabric.

A full range of wet-stretching condition was carried out but for the sake of simplicity only three levels are shown in diagram 8.

For this particular fabric the finished targets are 48-49 courses/3 cm at a finished width of 55 cms. The fabric was stretched to 11%, 25% and 38% over finished width as indicated by the broken bars but with a rib construction the fabric relaxes back very readily when it leaves the expander. The effect on fabric length is very clear, with the greatest width stretch level giving the greatest course level.

After drying, these course levels are largely maintained whilst at the same time the excessive width has been lost and in fact the fabric is below target width. After calendering, some loss of courses has occurred even though overfeed was applied and the width was slightly increased to allow for creep back. After transportation back to the UK and a delay of approximately 3 months some slight loss of width has occurred but the level of courses has been maintained.

This diagram demonstrates the benefits to be obtained by wet-stretching and that with a suitable dryer the reduction in length achieved during wet-stretching can be maintained and the excess width lost. The effect of the calender on courses is also apparent but it was practice in this factory to roll the fabric after calendering rather than precision plaiting. On a modern calender with a low tension precision plaiter, it should be possible to at least maintain the level of courses. Although this processing route has enabled us to approach our finishing targets we are nevertheless still outside specification although we are considerably closer than with the traditional processing routes.

During the four years between the last two ITMA's a number of machinery builders have been developing a new generation of drying machines which have the potential of overcoming some of the shortcomings of existing drying equipment. There isn't time today to describe all of the machines in detail but this development is important enough to warrant spending some time outlining the basic principles of operation of one or two of them.

To obtain low shrinkage values to the tumble test, consolidation of the fabric structure must be encouraged to occur during the drying of the fabric during processing. Mechanical agitation, particularly in the later stages of drying, would appear to be the major requirement together with a high drying efficiency. This mechanical agitation can be induced in a number of ways. One popular method is to alter the direction or sequence of the air jets so that the fabric is maintained in a state of agitation as it is transported through the drying enclosure.

Diagram 9 shows the mode of action of the Kiefer Rotoswing dryer. The fabric is transported through the machine between two continuous conveyor bands. Either one lane of fabric or several lanes of fabric can be processed continuously. The fabric is overfed onto the lower conveyor and as it is transported through the machine it is intensely ventilated by means of a special nozzle system. The lower nozzle system is fixed whilst the upper nozzle system is reciprocated which results in three phases of fabric ventilation. The resultant fluttering movement of the fabric against the upper and lower conveyors induces consolidation of the fabric structure.

The Haas "Aerovar" continuous tumbler (diagram 10) uses a single conveyor to transport the fabric through the drying enclosure but the air flow is alternately directed from above and below the fabric. In Phase 1 the upward surge of air lifts the fabric and forces it against angled baffle plates. In Phase 2 the air flow is directed to the upper nozzles and this forces the fabric back onto the conveyor band. This continuous agitation again enables fabric consolidation to occur.

The work carried out by IIC and others would indicate that this mechanical agitation is only necessary in the later stages of drying (below 30%) and therefore the initial stages of drying (down to 30%) could probably be carried out on a conventional high efficiency dryer with perhaps a single bay dryer of the latest type run in tandem. We do not have any experience of such an arrangement at this time. We do have experience of a Kiefer "Rotoswing" dryer, however, and I would like to show the results from a trial which we carried out in conjunction with wet-stretching.

Diagram 11 illustrates the three levels of wet-stretching - 0%, 30% and 50% and the relationship between relative length and width after stretching is clearly seen. After drying on the Kiefer "Rotoswing" the differences in width and courses between the three treatments are very much smaller. The consolidation of the knitted structure is very apparent in the large increases in courses/3 cm and the big loss in width. At this stage the fabric has more courses than is required to meet specification and the excess width caused by wet-spreading has been eliminated.

The fabric is calendered slightly wider than target to allow for creep-back on standing and even though overfeed was applied there has been a slight loss of courses due to the reduction of fabric thickness. After a period of storage, the width has relaxed down to target and the course levels are at, or slightly better than, target.

Using a combination of wet-spreading and drying on one of the new generation dryers it is clear that we can now achieve targets which were largely unattainable using conventional equipment unless a compressive shrinkage treatment was included. Also it would appear that the wet-stretching conditions are not as critical when using the new type of dryer. This observation, however, is based on trials using one make of dryer only and further work is required to confirm whether other makes will give similar results.

Although the machinery builders have, without doubt, made a major contribution to helping finishers meet present day specifications, these new generation dryers are not universally suitable for all fabric types. In many ways these dryers simulate a domestic tumble dryer including some of the drawbacks:

- we have already seen in a previous paper what happens to a single jersey fabric made from singles yarn when it is dried in a tumble dryer. Considerable spirality can occur. The same applies if such a fabric is dried on one of the new types of dryer, making it virtually impossible to straighten the fabric at the calendering stage.

- if a fabric is anything other than a plain construction (stripes, checks, weft insert etc) then any differential shrinkage due to a variable structure is exaggerated and fabrics can be distorted at the end of the dryer.

- the mechanical agitation in the dryer can sometimes have an adverse effect on the surface appearance due to hairiness formation.

- the large loss in width which occurs during the drying can sometimes make it difficult to attain target width at the calender. With some fabrics, width creep-back can also be a problem after calendering.

So, although it is without doubt a major step forward for a large proportion of fabrics, it is not a universal solution. No doubt manufacturers will be working to overcome some of these drawbacks and we can look forward to some interesting developments in time for ITMA '87.

2. FABRIC - CHANGING THE REFERENCE STATE

So far the processing methods to which I have referred have been for treating fabrics which are still in tubular form. Invariably the fabric is maintained in tubular form even on the laying tables in the making up factory. (Diagram 12).

In some circumstances, however, it is not possible to finish fabric in tubular form, for example:

- where a printed design is required
- fabric lay requirements rule out the use of tubular fabrics
- tubular finishing machinery is not available

Under these circumstances the usual procedure is to keep the fabric in tubular form during the wet processing sequences (bleaching, dyeing, etc) and to slit the fabric into open-width at as late a stage as possible. Final finishing normally comprises of stenter drying the fabric with the maximum of overfeed. Using such a sequence it is extremely difficult to reduce fabric length sufficiently to ensure that the finished fabric will exhibit low residual shrinkage to the tumble test.

To overcome the limitations of such a processing sequence many companies have found it necessary to carry out a chemical crosslinking treatment to reduce the potential shrinkage of the finished fabric. In some cases this has been done on equipment which was installed primarily for the processing of synthetic fabrics resulting in considerable problems for the finisher due to inconsistencies and fabric damage. Before outlining the crosslinking process and discussing the requirements which it places on equipment and chemicals, I will first of all describe the effects of crosslinking on the fabric structure.

Diagram 13 shows the effect of applying increasing amounts of a crosslinking agent to a 14 gauge 1 x 1 rib fabric. Finished without crosslinking agent but using the same equipment this fabric showed a 15% length shrinkage to the tumble test. By applying just over 2% crosslinking agent (solids based on fabric dry weight) the potential length shrinkage has been reduced by half. Doubling the crosslinking agent reduces the shrinkage to approximately one-third. In every case, the construction of the fabric at the end of the finishing operation was virtually the same (similar courses/3 cm similar weight and width) and yet length shrinkage differs considerably. The reason for this is shown in Diagram 14.

The upper curved line represents the reference courses for the various levels of crosslinking. The lower line is a hypothetical line which signifies the best which might be achieved in terms of course density using the mechanical overfeeding facilities of the stenter. Potential length shrinkage is indicated by the difference between delivered courses and reference courses and the effect of applying crosslinking agent is to alter the reference courses.

Diagram 15 shows the effect of crosslinking agent on the relaxed wales and the effect is minimal. There is a very slight increase in the relaxed wales as the concentration of crosslinker is increased but this effect is extremely small. This means that fabrics can be finished to the same width as the corresponding uncrosslinked fabric with roughly the same level of residual width shrinkage. It is well known that when crosslinking agents are applied to woven cotton fabrics up to 50% loss in tensile strength can be expected and allowance is normally made for this when designing new constructions which will subsequently be given a crosslinking treatment.

Strength loss is also to be expected when crosslinking cotton knitted fabrics and even at commercial levels of crosslinking (around 2% o.w.f.) the loss in bursting strength can be of the order of 40% (diagram 16).

Although a crosslinking treatment can be carried out on tubular fabric, and this is carried out on a considerable scale in the USA, the majority of crosslinking of knitted fabrics carried out in Europe is in open-width and therefore I would like to limit my comments to this technique.

The equipment required to carry out the crosslinking treatment is a pad mangle (diagram 17) linked by a low tension compensation system to a knitgoods stenter. The feed zones of most modern knitgoods stenters are adequately equipped with guiding, straightening, overfeeding and edge gumming facilities. The heated enclosure should be as long as possible and certainly no shorter than 5 or 6 bays. Temperatures of up to 180°C should be attainable and controllable within fine limits. Direct gas heating is generally to be preferred to an indirect heating system. The delivery end of the stenter should incorporate a cooling zone and a fully reliable and well maintained selvedge trimming device. The operations of drying and curing must be achieved during a single passage down the stenter and this is where many of the problems occur.

It is apparent that the time available for curing is dependent on how quickly the water is removed from the fabric and how quickly the fabric attains curing temperature. The precise drying time is seldom known in advance and moreover it can vary during a production run even at a constant fabric speed due to several factors which affect the time of drying. This uncertainty in the time of curing places certain limitations on the crosslinker/catalyst system which can be used, together with the other requirements demanded of the system. Briefly, these are as follows:

a. Relatively short curing times, of the order of 15-30 seconds must be possible, therefore, a fairly reactive crosslinker and an active catalyst must be employed.

b. The fabric must not require a subsequent after-wash due to the presence of potentially irritant residues.

c. Excessive catalytic damage must not occur if the curing time is exceeded.

d. The chemicals employed must not have an adverse effect on shade and fastness of dyed fabrics.

e. The treated fabric must not smell of formaldehyde nor develop formaldehyde smell in storage.

f. The treated fabric must not develop fish-like smells which can occur if certain catalysts are used.

g. The crosslinker/catalyst system must give the required fabric stability with the minimum of strength loss.

Clearly these requirements place a great deal of restriction on the choice of crosslinking agent and catalyst and a particular system may have to be tailored for a particular finisher. I do not propose to discuss these now but would be happy to discuss them with anyone who is interested during the discussion periods.

As well as crosslinking agents and catalyst, many other finishing auxilliaries can be applied in the same finishing bath. These range from fibre protective agents, stitch lubricants and handle modifiers to proofing agents and elastomeric finishes. As well as improved dimensional stability the crosslinking treatment also confers a number of other properties:

- improved easy-care
- reduced curl on single jersey
- reduced spirality on single jersey made from singles yarn
- better garment shape and appearance retention
- retention of lustre on mercerised fabrics
- improved dye fastness

The crosslinking process, however, cannot be carried out as a stop-gap method of shrinkage control. It requires serious consideration and the knitter, the finisher and the customer must all be fully aware of the implications of carrying out such a treatment and specifications must be drawn up accordingly.

CONCLUSIONS

In conclusion, I hope I have been able to demonstrate that knitgoods finishing technology has advanced to a stage where the increased demands of the outerwear market can now be met by the finisher provided he is prepared to invest in the latest equipment and know-how. Some of the measures open to him however can result in a need for a reappraisal of the fabric specification and close collaboration with knitters and makers-up is essential. The implications of installing new plant or changing methods should be discussed openly so that if need be, changes in fabric specification can be made to compensate for these changes.

Diagram 1

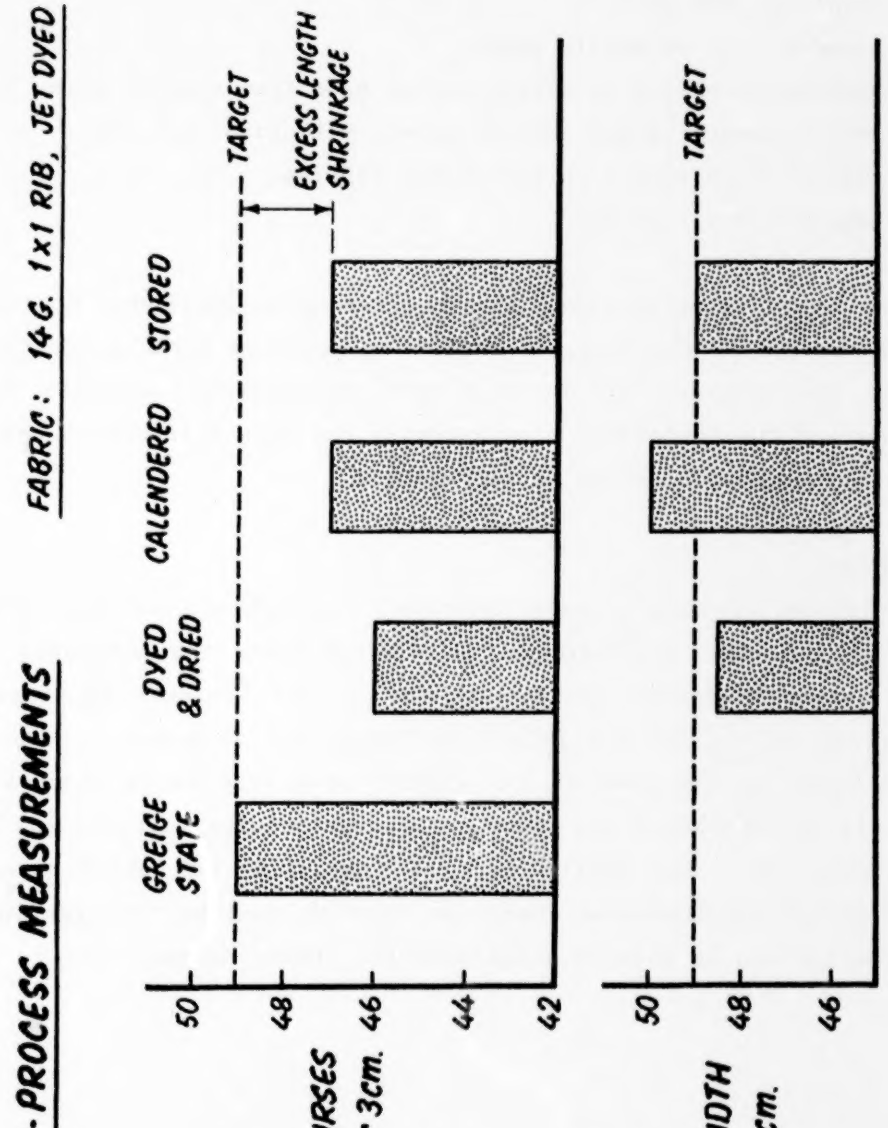

IN-PROCESS MEASUREMENTS
FABRIC: 14G. 1x1 RIB, JET DYED
GREIGE STATE
DYED & DRIED
CALENDERED
STORED
TARGET
EXCESS LENGTH SHRINKAGE
COURSES per 3cm.
50
48
46
44
42
TARGET
WIDTH cm.
50
48
46

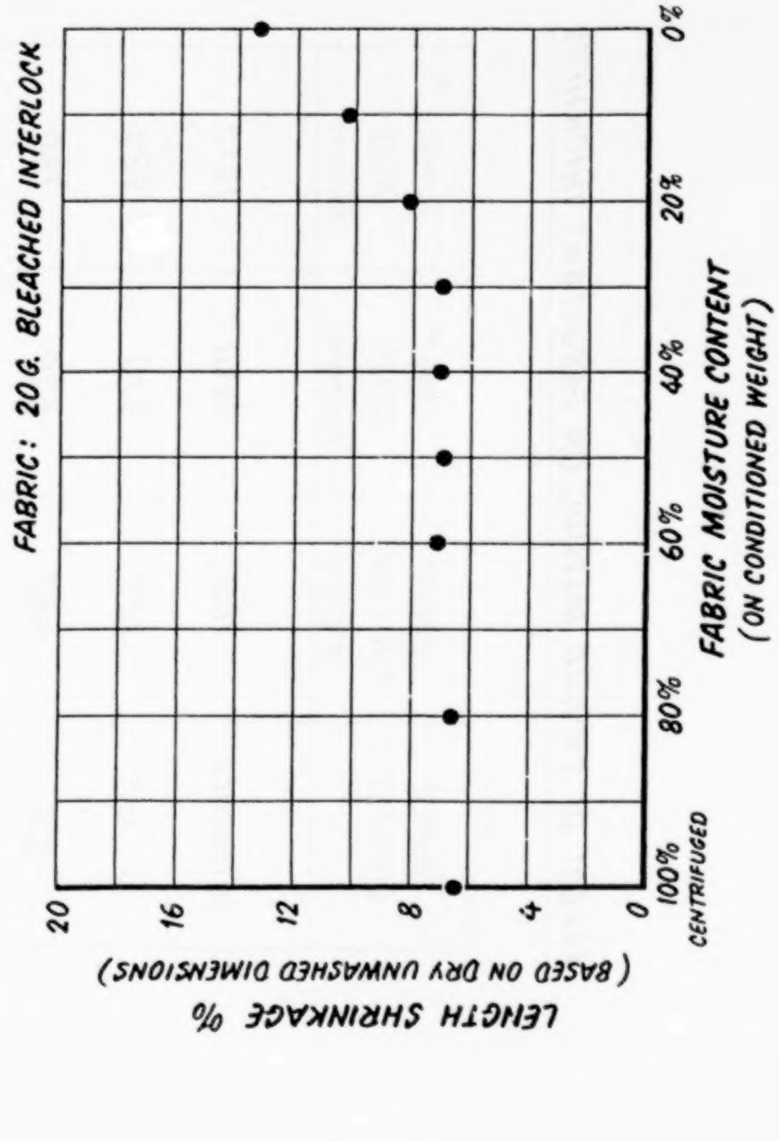
Diagram 2

EFFECT OF DRYING METHOD ON RESULTANT THICKNESS

FABRIC QUALITY	AFTER FINISHING microns	LINE* DRIED microns	TUMBLE* DRIED microns
INTERLOCK	760	1030	1210
1x1 RIB	720	870	980
S.J.	480	620	750

* 5 CYCLES

Diagram 3



LENGTH SHRINKAGE DURING TUMBLE DRYING

Diagram 4 and 12

BASIC APPROACHES TO A SOLUTION

EQUIPMENT

- LENGTH/WIDTH INTERCHANGE
- DEVELOPMENT OF FABRIC THICKNESS
- OVERCOMING INTERYARN FRICTIONAL FORCES

FABRIC

- CHANGE THE REFERENCE STATE BY CHEMICAL CROSSLINKING

DIAGRAM 5

Close up photography of the
stretching mechanism of the Calator 'Airtex'

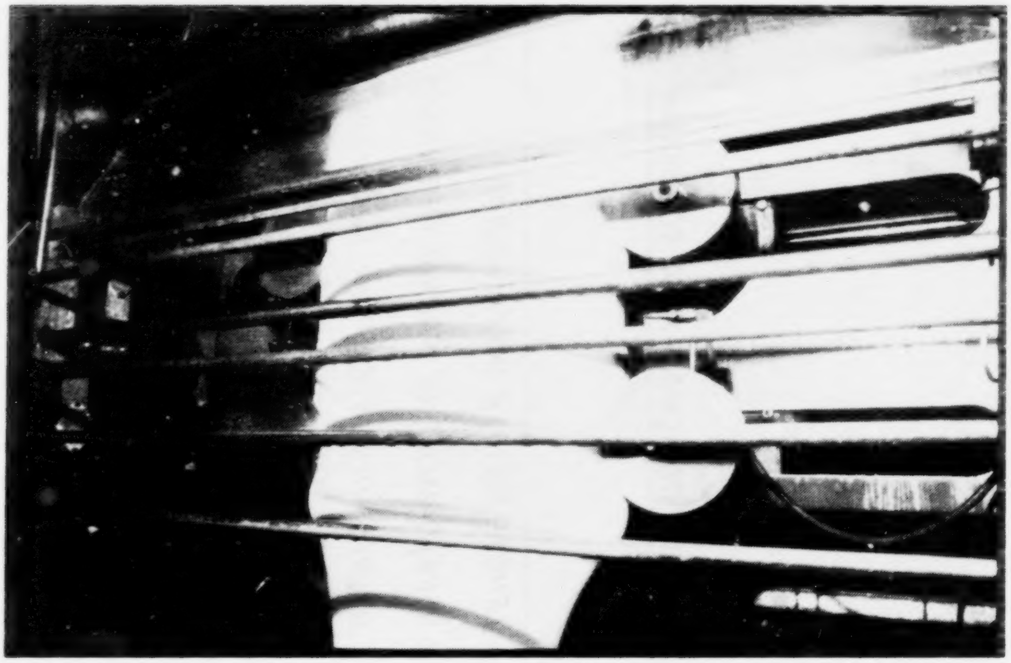


DIAGRAM 6

Overall photograph of
the Calator 'Airtex'

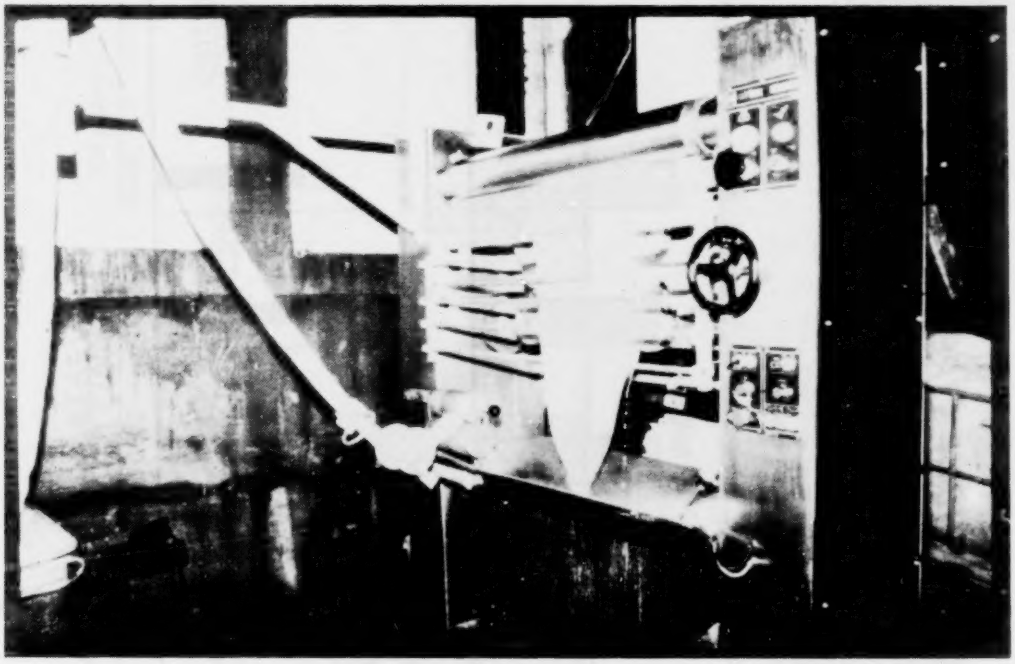
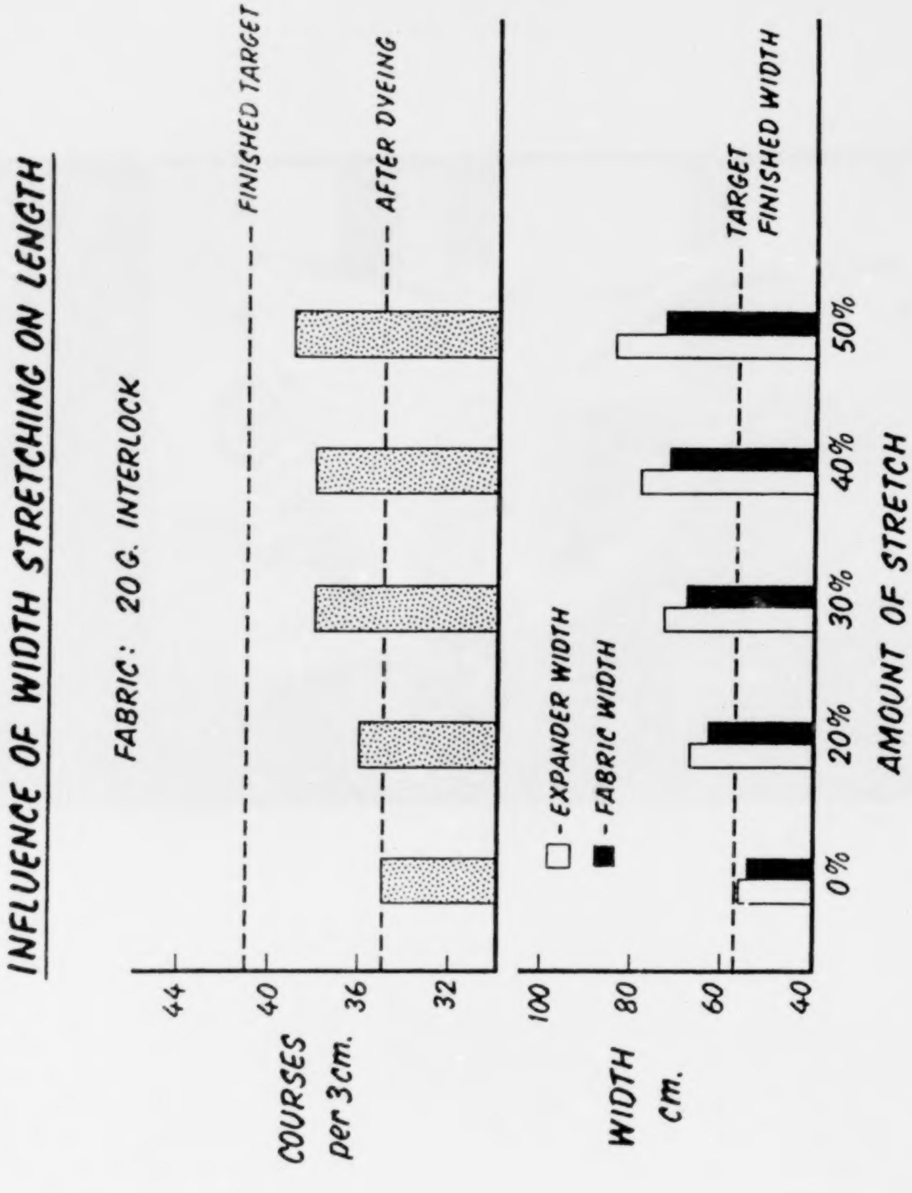


Diagram 7



INFLUENCE OF WIDTH STRETCHING ON LENGTH

Diagram 8

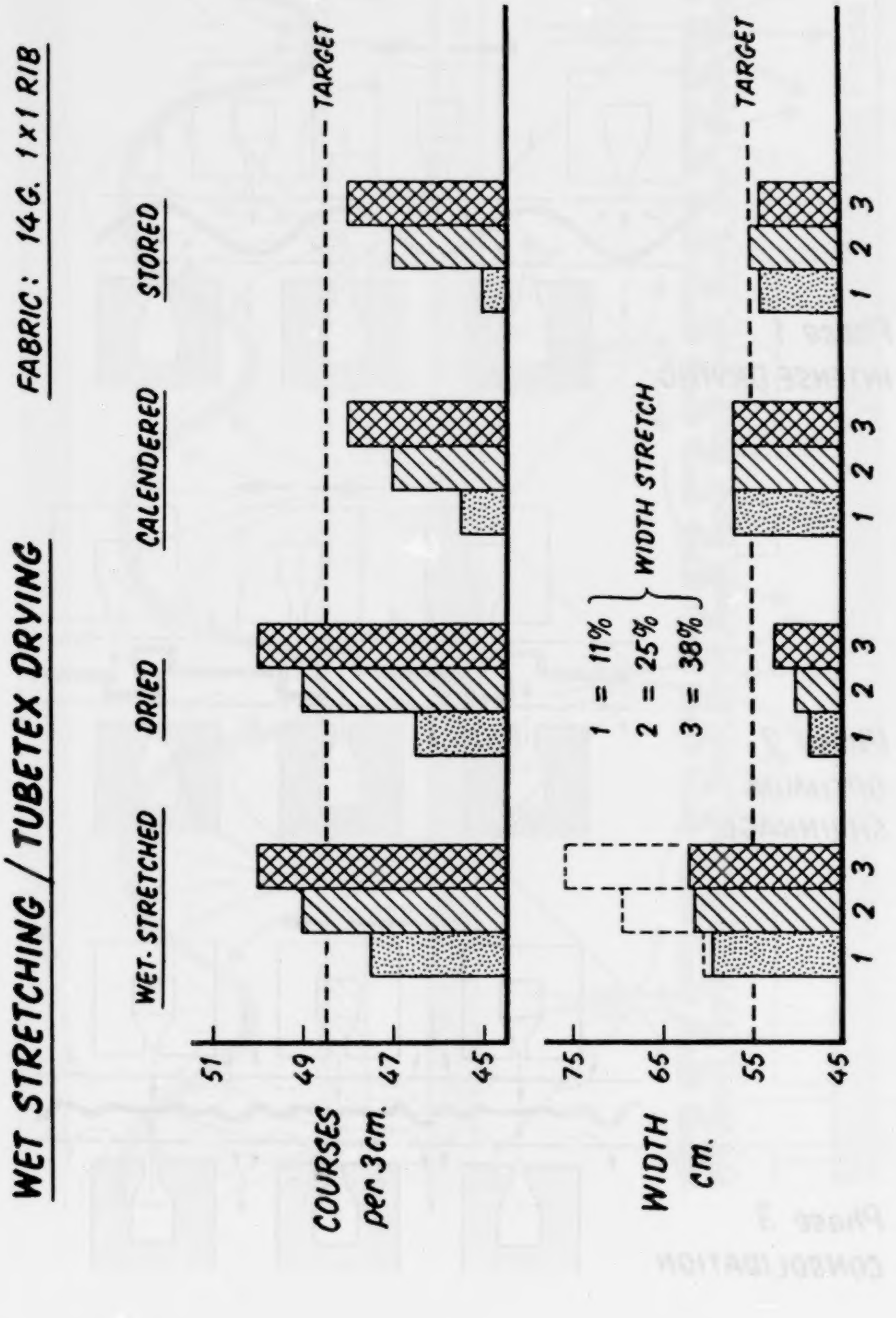
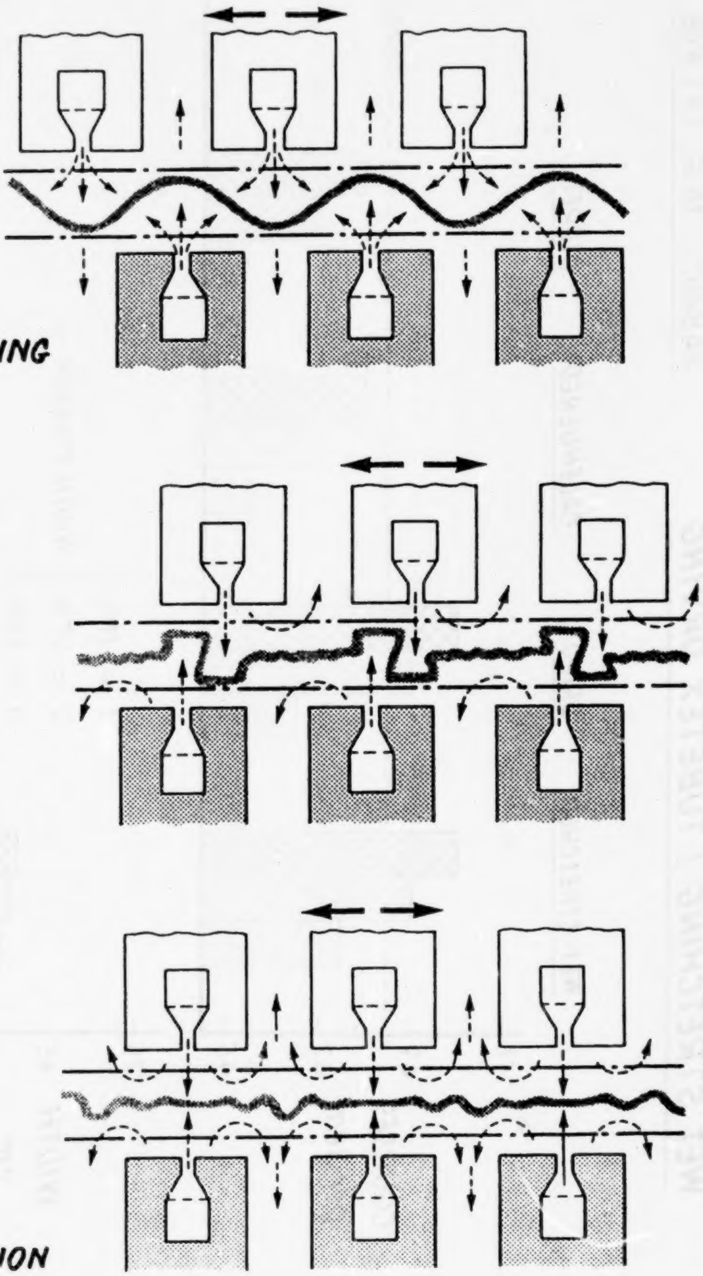

WET STRETCHING / TUBETEX DRYING
FABRIC: 14G. 1x1 RIB
WET-STRETCHED
DRIED
CALENDERED
STORED
TARGET
COURSES per 3cm.
51
49
47
45
WIDTH cm.
75
65
55
45
1 = 11%
2 = 25%
3 = 38%
WIDTH STRETCH
TARGET
1 2 3
1 2 3
1 2 3
1 2 3

Diagram 9

KIEFER 'ROTOSWING' DRYER



Phase 1
INTENSE DRYING

Phase 2
OPTIMUM
SHRINKAGE

Phase 3
CONSOLIDATION

HAAS 'AEROVAR' CONTINUOUS TUMBLER

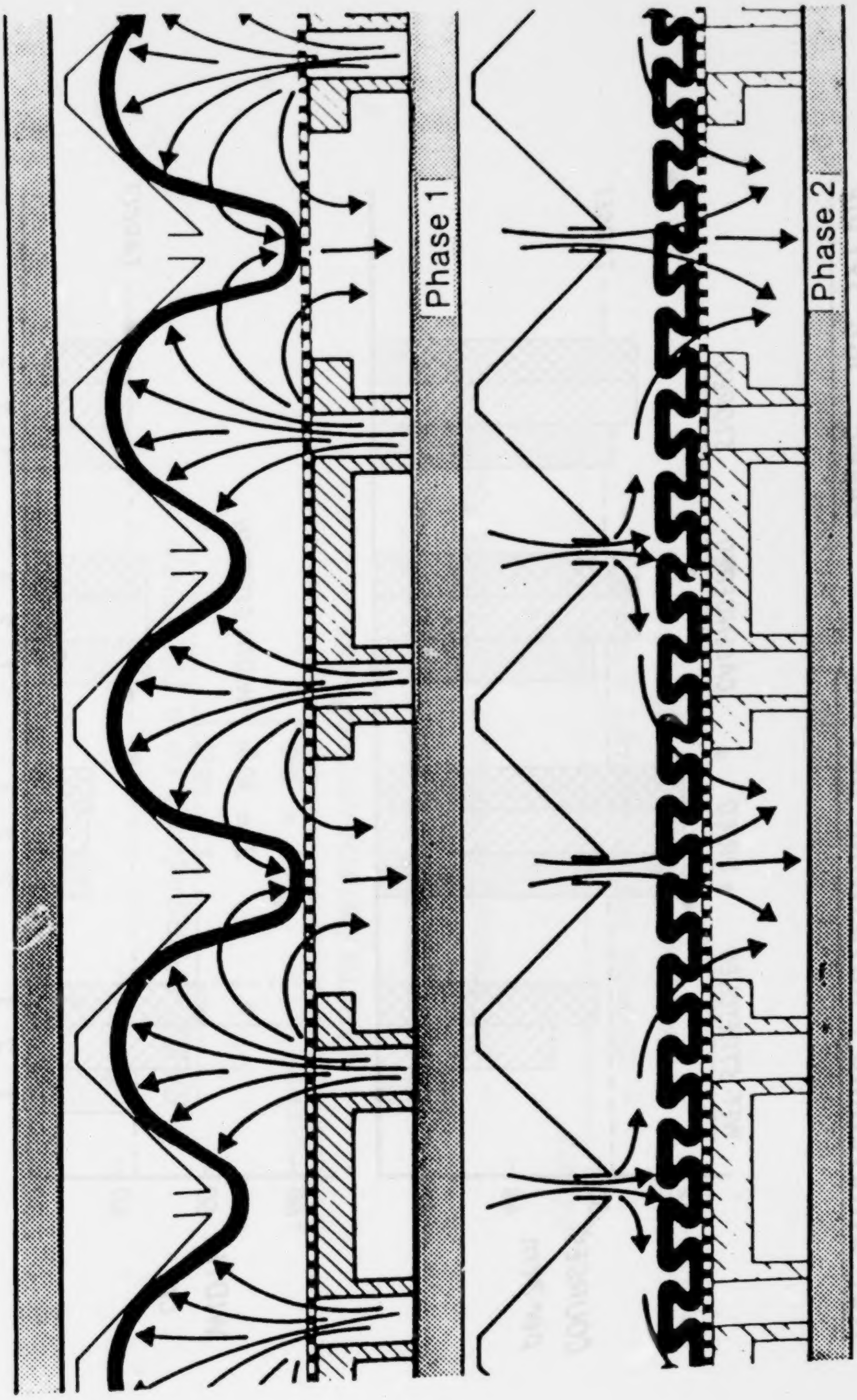

Phase 1
Phase 2

Diagram 11

WET STRETCHING / ROTOSWING DRYING

FABRIC: 14G. 1x1 RIB

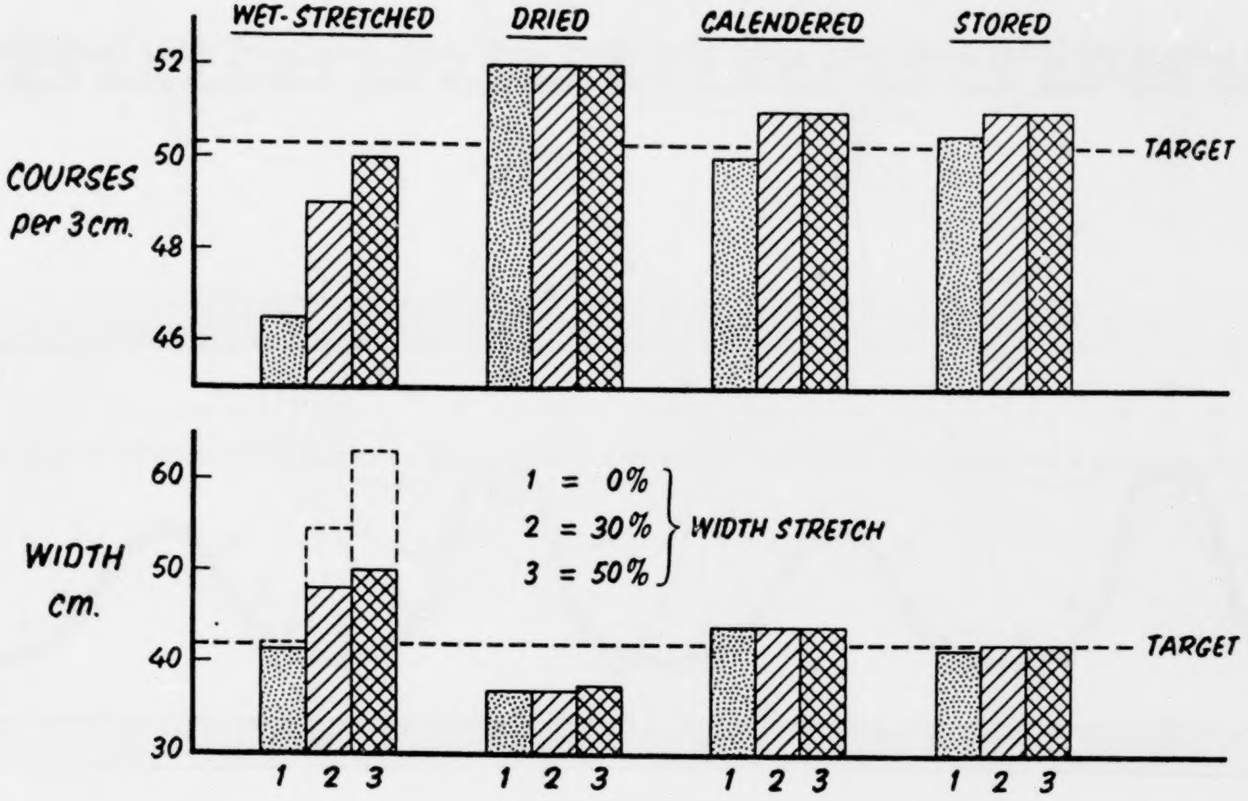


Diagram 4 and 12

BASIC APPROACHES TO A SOLUTION

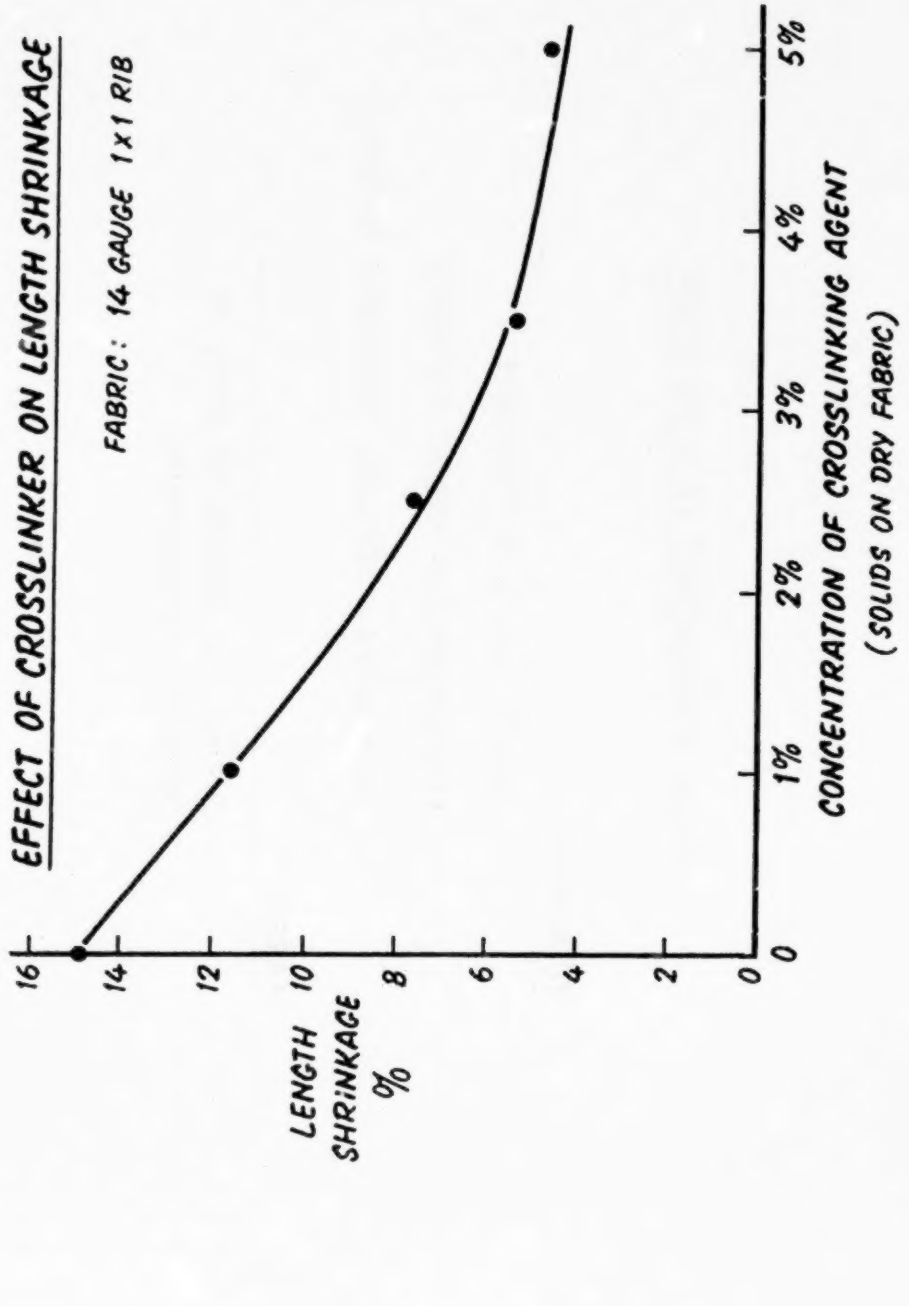
EQUIPMENT

- LENGTH/WIDTH INTERCHANGE
- DEVELOPMENT OF FABRIC THICKNESS
- OVERCOMING INTERYARN FRICTIONAL FORCES

FABRIC

- CHANGE THE REFERENCE STATE BY CHEMICAL CROSSLINKING

Diagram 13



EFFECT OF CROSSLINKER ON LENGTH SHRINKAGE

FABRIC: 14 GAUGE 1 x 1 RIB

Diagram 14

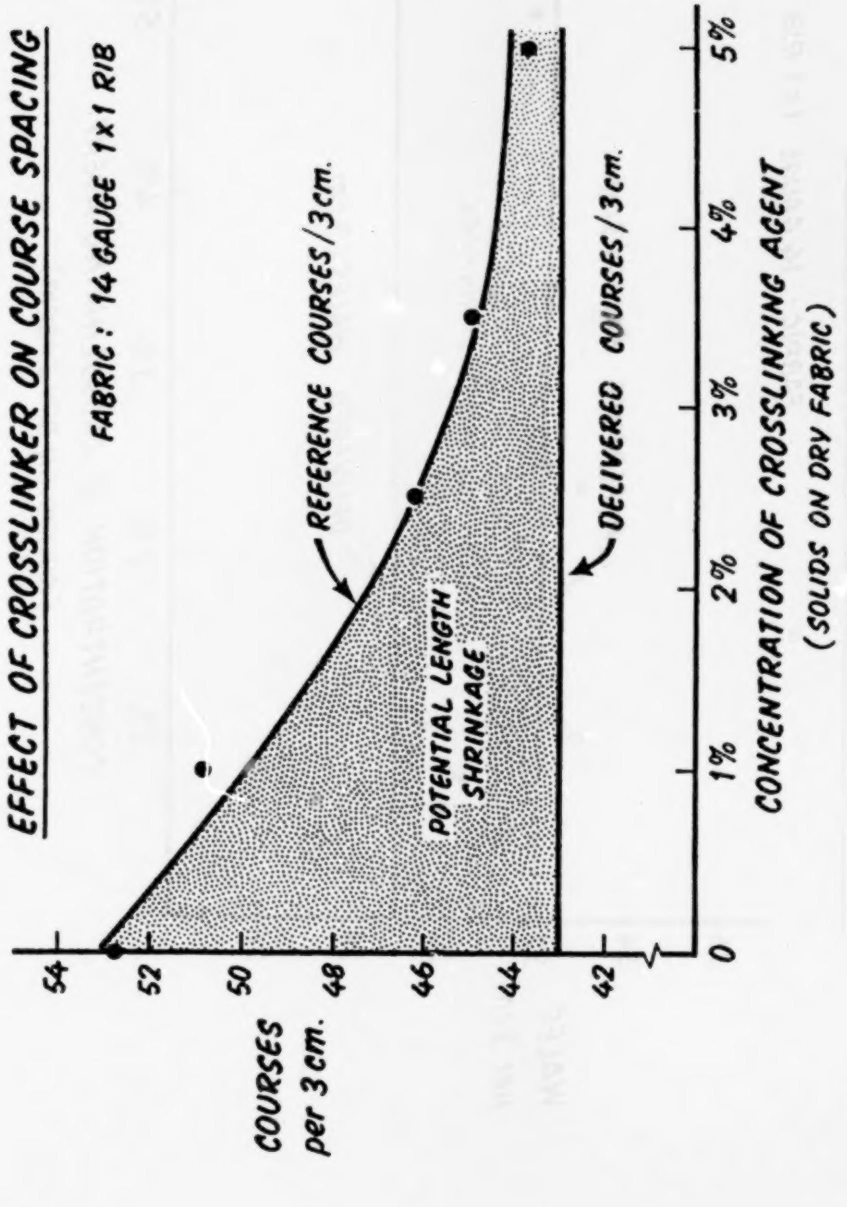

EFFECT OF CROSSLINKER ON COURSE SPACING
FABRIC : 14 GAUGE 1x1 RIB
REFERENCE COURSES/3cm.
DELIVERED COURSES/3cm.
POTENTIAL LENGTH SHRINKAGE
COURSES per 3cm.
54
52
50
48
46
44
42
0
1%
2%
3%
4%
5%
CONCENTRATION OF CROSSLINKING AGENT
(SOLIDS ON DRY FABRIC)

Diagram 15

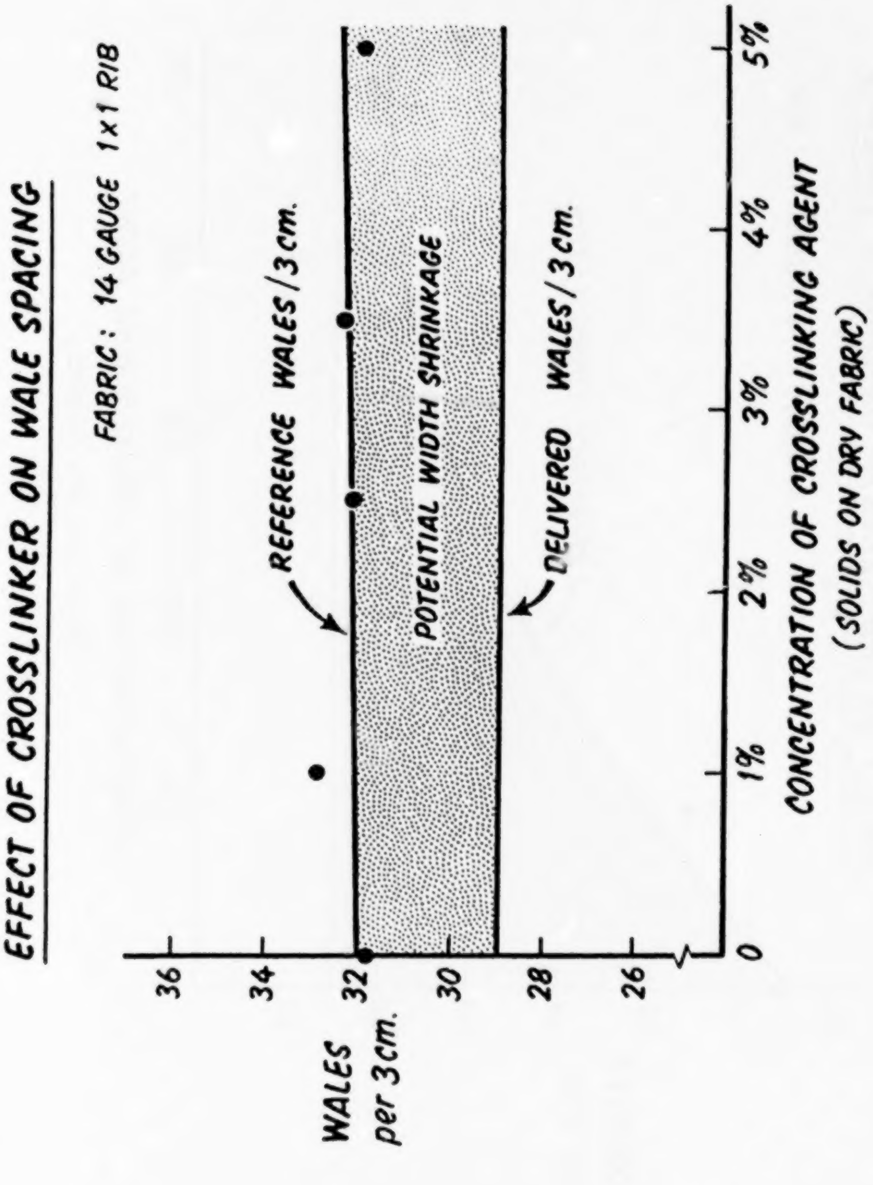

EFFECT OF CROSSLINKER ON WALE SPACING
FABRIC: 14 GAUGE 1x1 RIB
REFERENCE WALES/3 cm.
POTENTIAL WIDTH SHRINKAGE
DELIVERED WALES/3 cm.
WALES per 3 cm.
36
34
32
30
28
26
0
1%
2%
3%
4%
5%
CONCENTRATION OF CROSSLINKING AGENT
(SOLIDS ON DRY FABRIC)

Diagram 16

EFFECT OF CROSSLINKER ON BURSTING STRENGTH

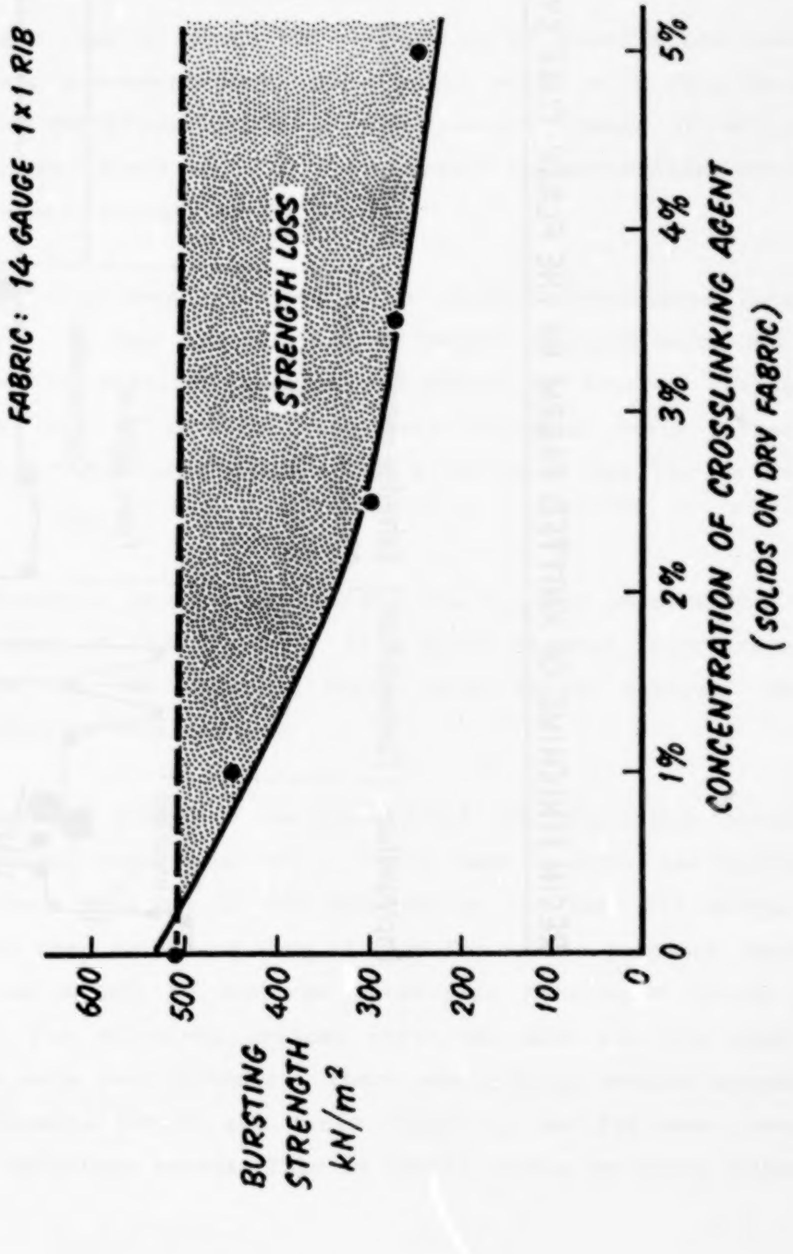
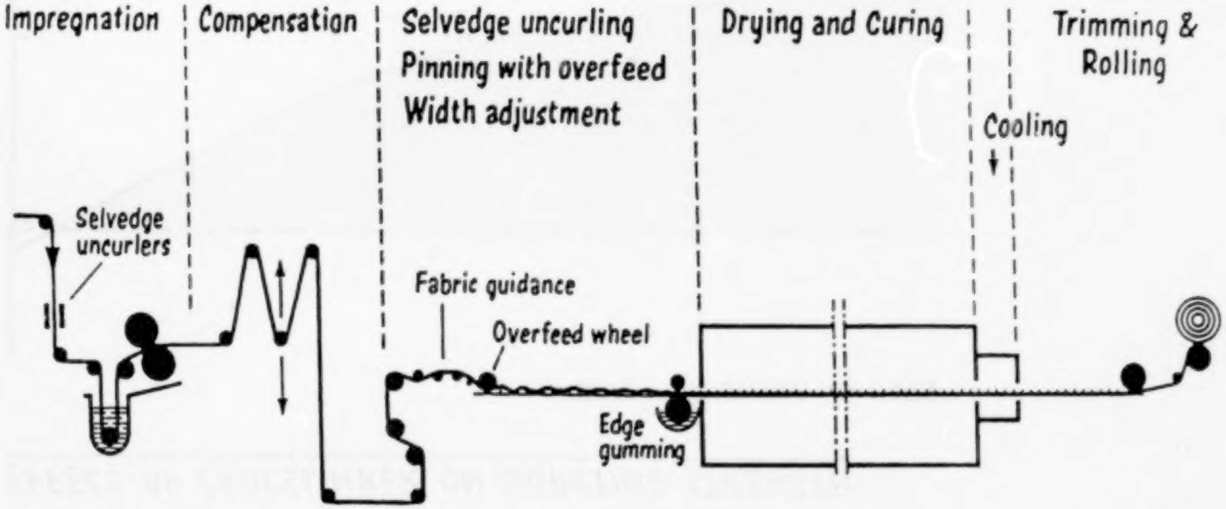


Diagram 17

RESIN FINISHING OF KNITTED FABRIC BY THE FLASH-CURE SYSTEM


Impregnation
Compensation
Selvedge uncurling
Pinning with overfeed
Width adjustment
Drying and Curing
Cooling
Trimming &
Rolling
Selvedge uncurlers
Fabric guidance
Overfeed wheel
Edge gumming

DISCUSSION

MR. P. F. GREENWOOD AND MR. R. D. LEAH'S PAPERS

Asked to give some idea of acceptable strength losses following crosslinking, losses in fabric bursting strength of about 40% were quoted, although it was pointed out that the reduction of yarn strength was perhaps more important. If the yarn strength was reduced too much, that yarn would tend to break rather than deflect during the sewing operation and produce a hole.

The quoted strength loss of around 40% referred to an unmercerised fabric. If the fabric was pre-mercerised, there would still be a considerable strength loss due to crosslinking but the overall change in strength from grey to finished state would be less because the mercerising process itself could increase strength by 20-30%.

The speakers were also asked to comment on abrasion resistance following crosslinking. It was agreed that it should be considered but it was not too easy to measure abrasion resistance on knitted fabrics. There must be a loss of abrasion resistance following resin finishing but only practical experience would tell a finisher how far he could go.

In reply to a question about flash curing the speaker pointed out the very critical nature of the process. In a short stenter, high temperatures were needed but any stoppage would cause fabric damage. There was no good solution to this problem.

In a further comment on dryers it was pointed out that the latest developments had come along rather quickly. There were several new machines on show at the last ITMA but it was only during the past six months or so that access had been gained to some of them for trials purposes. Mechanical agitation was needed to overcome inter-yarn frictional forces but it was felt that the vibratory devices which had been put into some of those new dryers were too vigorous. There was a happy medium somewhere and in the foreseeable future one could expect to see far more control of the degree of agitation because fabrics varied widely in their tolerance to agitation.

It was remarked from the floor that the price of some of these dryers was very high; another delegate pointed out that some companies (e.g. Tubetex and Fleissner) were developing conversion kits for existing dryers which might not incorporate vibratory action but which would more effectively control tension in the fabric during drying.

During a lengthy discussion on wet spreading followed by drying, one of the speakers pointed out that the objective should be to achieve the desired number of courses in the fabric, not necessarily a tidy appearance. The latter could always be achieved later by final calendaring. Wet stretching did not appear to influence the reference state provided the stretching was not extreme.

Another questioner said that the reference state of crosslinked fabric had been mentioned - that surely must be different from that of the grey fabric. It was, he was assured, but the objective was to alter the reference state to bring it closer to the delivered state because shrinkage was due to the difference between the reference state and the delivered state. With current equipment there were limitations as to what could actually be achieved in terms of finished dimensions so if the reference dimensions could be altered then it was possible to alter the resultant shrinkage.

A final question concerned the use of dyed yarn as distinct from dyed fabric; would the same fabric quality standards apply? The speakers thought the actual standards would be slightly different. A STARFISH user commented that in his company, the fabric specifications would be nominally the same with possibly a difference of one or two courses between yarn dyed and fabric dyed materials.

STARFISH - A PREDICTIVE APPROACH

Mr. S. A. Heap
International Institute for Cotton

INTRODUCTION

In the four previous papers we have heard about:

- the need for improved control over shrinkage
- the need to standardise performance targets across a range of qualities and suppliers
- the need to be able to discover the reference dimensions of a given fabric quality in order to be able to set proper targets and to check out customer's specifications
- the fact that the dimensions of the reference state are determined for the most part by just a few important factors, namely the yarn, the knitted loop length, and the finishing route.

In the practical mill situation, finding out the dimensions of the reference state for a given fabric quality is a tedious and relatively expensive business even under the most favourable conditions. It is necessary to make numerous samplings and to test over a fairly extended period before one can have complete confidence in the results. Allowances have to be made for variations in the greige fabric and for differences in finishing procedures - for example a fabric dyed to a deep shade in a jet will have a different reference state to that of the same fabric dyed white in a winch.

In certain cases it may even be impossible to establish the reference dimensions by actual measurement. For example if a new product is to be introduced or if new finishing machinery is to be installed.

Therefore it would be useful if there were some way of providing a first estimate for the reference dimensions by calculation.

If we were able to predict reference dimensions by calculation we would have a direct method for:

- fixing appropriate manufacturing and finishing targets
- checking and revising customer specifications and tolerances, and

- simulating product development trials at reasonable cost in order to screen out unworkable ideas, guide quality control efforts and evaluate the technolcgical consequences of certain investment decisions.

During the course of our research and development work on the production and finishing of cotton knits, we began to collect large quantities of data in which the major factors influencing the reference state had been systematically varied.

Since we had made most of the test measurements by standardised methods and we had used a standardised relaxation procedure, it soon became obvious that the data base should be suitable for mathematical analysis in such a way as to produce prediction equations for the reference state.

Therefore we undertook to make such an analysis, to discover the appropriate equations and to build them into calculation systems which can be used in practical product design and development.

THE DATA BASE

At the present time our data base includes measurements on 1 x 1 rib, interlock and plain single jersey fabrics.

The count range in the 1 x 1 rib series is from Ne 26 to Ne 34, but that for the interlock extends from Ne 30 to Ne 70, and for plain single jersey we include Ne 1/16 to 1/40 and also Ne 2/32 to 2/80. All are combed ring yarns. Each of the yarns has been knitted in at least five different stitch lengths and each series of fabrics has been processed through several different finishing routes (Diagram 1). All of the manufacturing has been carried out on a commercial or semi-commercial scale and, at the last count, the total number of different combinations of fabric and finish is around 1500.

Each year we are adding more combinations of fabric and finish within these three basic fabric categories, the 1 x 1 rib, the interlock and the plain single jersey, as manpower and funds allow. Eventually we hope to branch out into other fabric types such as the single jersey lacoste and other yarn types, such as OE rotor yarns.

ANALYSIS OF THE DATA

In our analysis of the data base in order to develop prediction equations we have started out by imposing two major limitations.

The first of these is that the general form of the equations has to be broadly compatible with what has been found by earlier workers who have studied such problems.

The second limitation that we have imposed is that we have restricted the input parameters for the equations to those which are known before knitting commences and which can be measured easily in a mill laboratory. This means that we can take no account of such interesting yarn properties as bending stiffness or specific volume but it does allow us to proceed with a practical and workable system.

Diagram 2

When we look back at the way that earlier workers have approached this problem, we find that they often start from a consideration of plots such as this which shows the dependence of relaxed courses and wales per cm on the reciprocal of stitch length for jet dyed and finished plain single jersey. It has usually been found that the relationship is a simple and linear one, and that one may therefore estimate the so-called dimensional constants, or K factors, Kc and Kw from the average slope of the lines or from the average values of courses x stitch length or wales x stitch length.

Looking in the literature we can find estimates for Kc and Kw for various types of cotton knits and so it is a simple matter to calculate the relaxed courses and wales for any of these fabrics for a given knitted stitch length. Once the courses and wales are estimated, then all other dimensional properties can be calculated provided that the yarn count and the number of needles in the knitting machine are known.

The only problem with this nice simple approach is that it does not actually work very well in practice when we attempt to use the factors over a wide range of finished qualities. There are several reasons for this.

Diagram 3, 4 and 5

The first reason is that most of the K factors which one finds in the literature refer to greige fabrics. When we calculate the K factors for finished fabrics we find significant differences according to the finishing route.

Diagram 6
The second reason is that the average K values are strictly applicable only to the average fabric. When the yarn count and stitch length are significantly different from the average for which the factors were calculated, then we find significant errors in the calculated courses and wales, compared to those actually measured.

This leads us to the third reason which is that the classical K factors take account only of variations in the stitch length as knitted and this one parameter is not adequate to explain all of the variations in finished dimensions.

Diagram 7
This diagram shows the dependence of the ratio of courses to wales on yarn count as well as stitch length, and proves that the yarn count also has a significant influence upon the courses and wales. If we want to make reliable predictions then the influence of the yarn must be taken into consideration.

In our analysis we have tried to take account of these problems and we have derived a set of relatively simple equations which allow for variation in yarn count and finishing route, as well as for variation in stitch length.

Diagram 8
These equations have been built into a computer model which allows one to predict the dimensions and the shrinkages of a range of plain jersey, 1 x 1 rib, or interlock fabrics starting from the knitting specification and allowing for stipulated finishing targets.

The model has been named STARFISH which is short for "Start as you mean to finish". The name is supposed to embody the idea that any given finishing routine is expected, in principle, to exert a unique influence upon the final (relaxed) dimensions of a given quality of fabric. It is therefore desirable to be able to predict the finished dimensions before you start to knit the fabric.

The computer model works in three steps:

Diagram 9
Step 1 converts the original yarn count and stitch length into the values which are expected to be found in the finished, reference state.

Diagram 10
Step 2 employs the equations of the reference state to calculate the relaxed courses and wales starting from the reference count and stitch length.

Diagram 11
Step 3 converts the relaxed reference dimensions into those which would be expected in the fabric as delivered by the finisher, provided that he has correctly met his finishing targets. Finishing targets may be set in one of three ways:

- according to length and width shrinkages
- according to finished courses and wales
- according to finished weight and width

Diagram 12
Using this model we find that relaxed courses and wales can now be predicted to within acceptable agreement with those actually measured over the full range of fabric qualities and finishing routes for which the model is presently applicable.

Diagram 13
Likewise, we are able to obtain good predictions for shrinkage ....

Diagram 14
.... and for the finished weight.

During the past two years, we have been able to check out the reliability of the model in practice by sampling a few qualities in the industry.

Diagram 15
This diagram shows the average values of relaxed dimensions together with their standard deviations, for two qualities sampled over a period of a

few months in a UK manufacturer's mill. Alongside the measured results are shown those which are predicted by the STARFISH model and you can see that the predictions are generally within one standard deviation of those actually measured.

Diagram 16

This diagram shows the data for the same two qualities but this time the dimensions are those of the fabrics in their finished state, as delivered. Once again you will see that the agreement is very good.

APPLICATION

Thus we feel that we have the beginnings of a useful, practical system for predicting the finished dimensions of knitted cotton fabrics. The present STARFISH model is only a start since we are well aware that our basic equations are capable of much improvement and our data base is certainly much too narrow. Both of these limitations will be gradually lessened with the passage of time and the further investment of manpower and money.

Diagram 17

Meanwhile we should make good use of what we already have and this diagram illustrates a few of the possible areas where the system can be put to work.

I would like to spend the rest of my time by working through one specific example of how the system could be used, which embodies all of these different aspects in one way or another.

The example concerns the field of body-width tubular fabrics; it is a simplified and amended version of a study which we have actually carried out to assist a European manufacturer.

For a manufacturer who wishes to enter this field there are at least three basic technological problems to solve:

- choosing the correct size of knitting machine. This may involve capital investment
- optimising the knitting quality for the chosen machine
- specifying the finishing targets, particularly the finished width and courses per cm, to produce the correct weight and shrinkages.

Diagram 18

Consider a manufacturer who would like to produce a 28-gauge single jersey body width range for T-shirts. In the existing markets he finds a competitive cloth which he establishes has been produced on a 1,404 needle machine with Ne 36 combed ring yarn at a stitch length of 2.70 mm. The finished width is 49 cm, the weight is 110 g/m^2, and the shrinkage is about 10% in each direction after the five cycle reference relaxation procedure.

The potential customer says that he likes the weight of this competitive fabric but he would really like to have somewhat lower shrinkage levels, say 8% x 8%.

Diagram 19

Thus our manufacturer's objectives are clear. He must identify the most suitable knitting machine, and he must perform the magical trick of producing the same weight of fabric from the same yarn but with reduced shrinkages by optimising the knitting quality for the chosen machine, and by setting the proper finishing targets.

Diagram 20

The knitting may present a problem since our manufacturer does not happen to possess a 1,404 needle machine. His existing equipment has 1,476 or 1,512 needles so he may have to consider the purchase of new equipment. Fortunately, by using the STARFISH model he can simulate the knitting on all three machines to see which is the most suitable before making any investment decisions. The first step is to establish the fit of the garment, whether tight or loose, and just how tight. Since each end-use is unique, this can only be done in consultation with the customer who will usually stipulate the finished width for a given body size.

However, we would like to suggest another useful definition of fit, which we are calling the Reference fit.

The reference fit is the ratio of the reference (relaxed) width of the tubular fabric to the nominal body width as defined in Diagram 21. Obviously, for a close fit, this ratio will be less than 1.0 whereas for a loose fit it must be greater than 1.0. The exact value chosen depends to a large extent upon the fabric type. For example, close fitting 1 x 1 rib garments, which are very extensible, will normally have a rather low value (may be around 0.8) whereas for single jersey the reference fit will be closer to 1.0. The question of what tolerances should be allowed on the reference fit for a given size range is a fairly complicated topic and will not be discussed in this simplified example.

Diagram 22

Once the fit has been agreed, the target reference width can easily be calculated as the body width multiplied by the fit. Then, using the STARFISH model, we must calculate the number of wales per cm to be expected in the reference state for the proposed fabric quality and finishing route. From this follows the theoretical number of needles required to produce the correct reference width.

It is, of course, very unlikely that a knitting machine will be available which has exactly the correct number of needles. Therefore, we must select the nearest machine and work the calculation backwards to see what would be the actual reference width and hence the actual fit. If this is near enough to our target, then all is well and we can proceed on the assumption that the chosen fabric quality may be suitable. If not, then the fabric quality must be changed by adjusting the stitch length and possibly the yarn count as well. These adjustments can be simulated by STARFISH.

Diagram 23

This diagram shows the results of such a series of calculations for our present example. The calculations are made for a nominal body size of 38 inches (96.5 cm) and a reference fit of 0.95.

The target reference width turns out to be 45.8 cm but we find that the competitive quality is actually going to produce a reference width of about 44 cm leading to a fit of 0.91 which is outside the tolerances for this product.

Therefore, for each of the three alternative knitting machines, a series of STARFISH predictions have been made, by varying the stitch length, until a quality was found which will produce the required reference width of 45.8

cm. We are now ready to see what will be the dimensions of the finished cloth if we are able to deliver it with a shrinkage of 8% in each direction.

The next step, therefore, is to calculate all the reference dimensions for the chosen qualities using the STARFISH model and then to build in the required shrinkages to arrive at the predicted properties of the finished fabrics as delivered.

If the predicted finished weight is acceptable then we have probably found a good match for our customer's requirements and can begin with the sampling trials. If not, then we must try again with a new quality or a revised specification.

Diagram 24

This diagram shows the results of the STARFISH calculations for the jet dyed and finished dimensions both for the competitive fabric and for our three possible alternative candidates. The first column confirms that, if the competitive quality is produced and is finished to the correct weight, then the shrinkage will be higher than the customer is asking for.

Alternative number one proves that the 1,404 needle machine can be made to produce fabric with about the same weight and lower shrinkage by increasing the stitch length. But our manufacturer would have to buy a new knitting machine to produce this cloth. The second alternative turns out to be just a little too heavy and the finisher may have slightly more difficulty in achieving the higher stitch density. However, if this density can be achieved and if a slightly heavier weight can be tolerated, then this fabric has the advantage that it can be produced on a machine which is already installed so that no capital investment is required. The third alternative is heavier still and may possibly be rejected at this stage on cost grounds.

Further compromises may need to be made between the weight and the length shrinkage and/or the fit in consultation with the customer, and the consequences of any such compromises can be predicted by using the STARFISH model. In any event, the provisional specification can be drawn up in the face of the realities of the situation so that the element of wishful thinking, which is present in so many customer specifications, can be minimised and hopefully, eliminated.

Thus, without knitting a single kilogramme of yarn, we have arrived at some clear technical options for manufacturing so that costings can be made and sampling trials can begin with the confidence that the final product is going to be at least fairly close to the original customer specification so far as the fit, the weight and the shrinkage are concerned.

In conclusion, I should perhaps repeat that, at present, the STARFISH models are in a preliminary form and that our data base covers only a rather narrow range of fabric types and finishing routes. The gradual broadening of the data base will require many years and will be rather expensive. This work is going forward in close cooperation with a limited number of private companies and national research institutes who will also be the first to use the models in commercial practice.

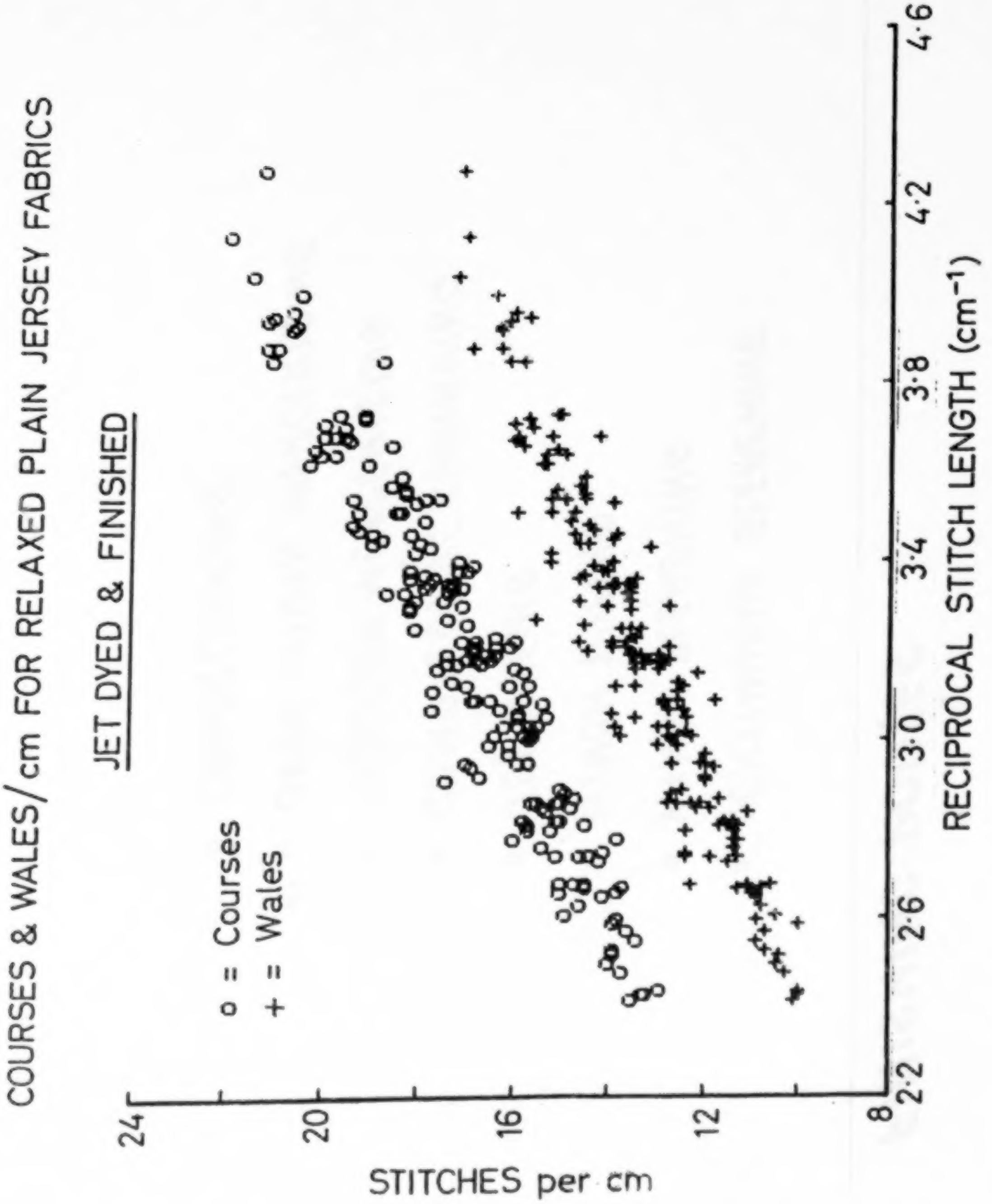
Eventually, we hope to see the day when the STARFISH system will be used as a routine technical management tool for solving day-to-day problems in the design, development and quality control of knitted cotton fabrics so that we all may "start as we mean to finish".

Diagram 1.

FINISHING ROUTES

- CONTINUOUS BLEACHING
- WINCH BLEACHING
- WINCH DYEING
- JET DYEING
- COMPRESSIVE SHRINKING
- TUBULAR MERCERISING
- OPEN-WIDTH MERCERISING
- CROSSLINKING

Diagram 2.


COURSES & WALES/cm FOR RELAXED PLAIN JERSEY FABRICS
JET DYED & FINISHED
o = Courses
+ = Wales
STITCHES per cm
24
20
16
12
8
RECIPROCAL STITCH LENGTH (cm^{-1})
2·2
2·6
3·0
3·4
3·8
4·2
4·6

Diagrams 3, 4 and 5

K_c AND K_w FOR 24g PLAIN JERSEY

	K_c	K_w	c/w
Singles yarns			
GREIGE	5·80	4·40	1·32
DYED	5·44	4·26	1·28
MERCERISED	4·74	4·95	0·96
Twofold yarns			
GREIGE	5·62	4·22	1·33
DYED	5·28	4·12	1·28
MERCERISED	4·36	4·98	0·89

K_c AND K_w FOR 20g INTERLOCK

	K_c	K_w	c/w
GREIGE	5·61	5·02	1·12
DYED	5·13	4·79	1·07
CROSSLINKED	4·46	4·90	0·91
MERCERISED	4·59	5·29	0·87
MERC. & CROSSLINKED	3·95	5·41	0·73

K_c AND K_w FOR 14g 1×1 RIB

	K_c	K_w	c/w
GREIGE	5·34	3·26	1·64
DYED	4·97	3·14	1·59
CROSSLINKED	4·51	3·23	1·41
MERCERISED	4·61	3·51	1·32
MERC. & CROSSLINKED	4·37	3·61	1·22

Diagram 6.

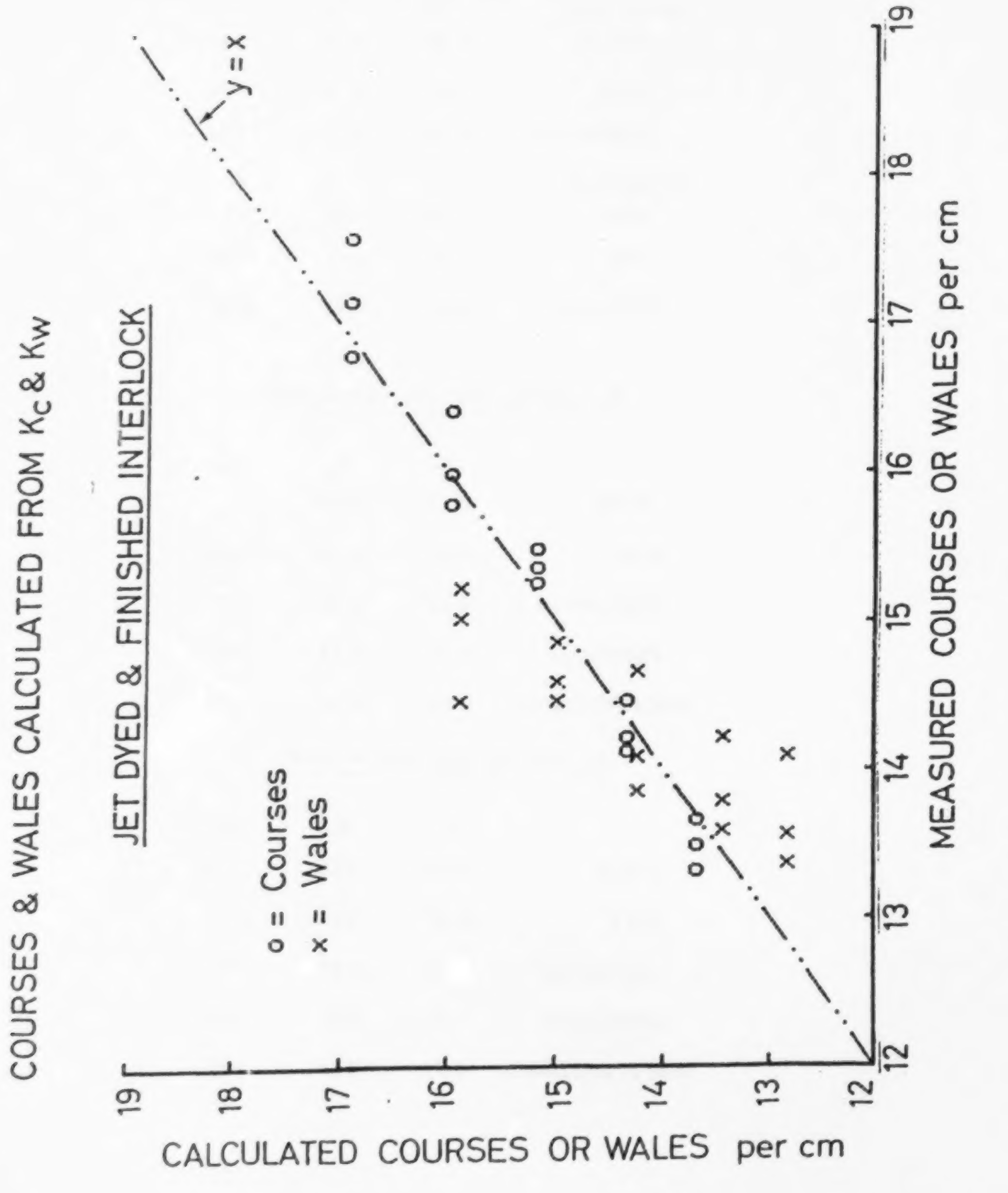
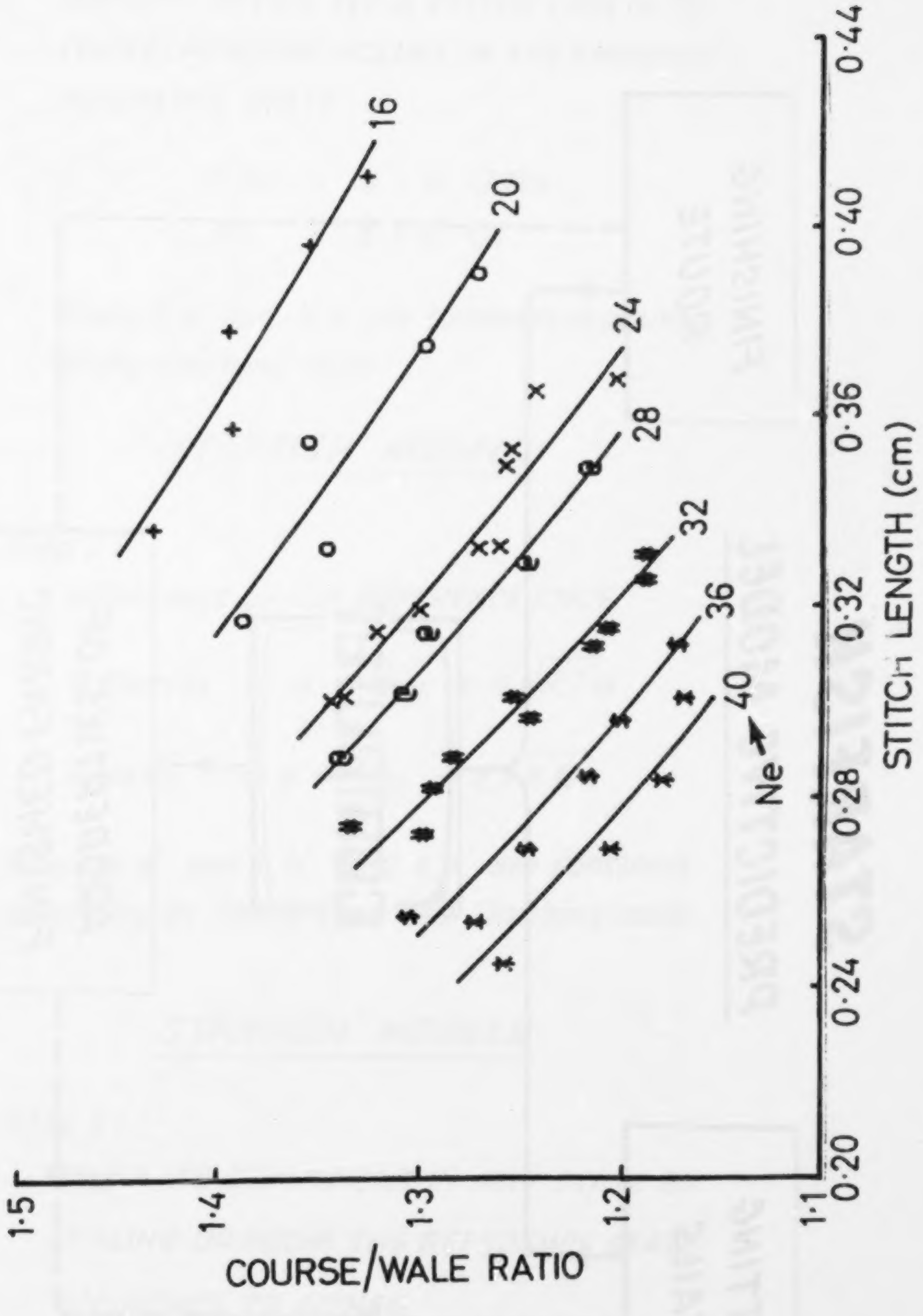
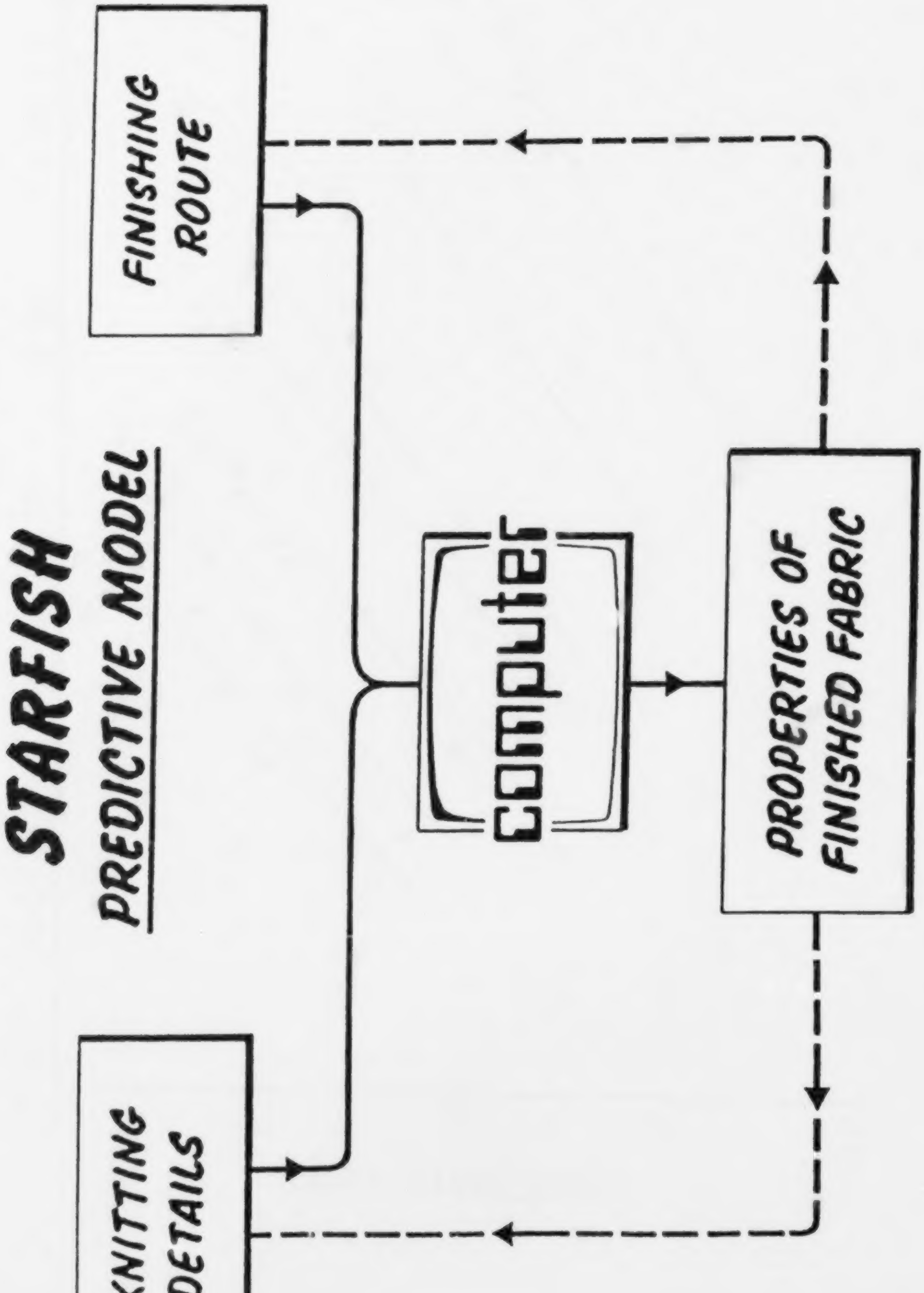

COURSES & WALES CALCULATED FROM K_c & K_w
JET DYED & FINISHED INTERLOCK
o = Courses
x = Wales
y = x
CALCULATED COURSES OR WALES per cm
MEASURED COURSES OR WALES per cm
12
13
14
15
16
17
18
19
12
13
14
15
16
17
18
19

Diagram 7.



COURSE/WALE RATIO FOR RELAXED DYED PLAIN JERSEY FABRICS

Diagram 8.


STARFISH
PREDICTIVE MODEL
KNITTING DETAILS
FINISHING ROUTE
computer
PROPERTIES OF FINISHED FABRIC

'STARFISH' MODELS

Step 1:

CONVERT GREIGE TEX & STITCH LENGTH TO CORRESPONDING VALUES IN THE FINISHED REFERENCE STATE

$$R\,Tex = a + b.\,G\,Tex$$
$$Rl = a' + b'.\,Gl$$

Where a, a' and b, b' are constants depending on the finishing route

'STARFISH' MODELS

Step 2:

EQUATIONS OF THE REFERENCE STATE

$$R\,Courses = a + b/_{Rl} + c.\sqrt{R\,Tex}$$

$$R\,Wales = a' + b'/_{Rl} + c'.\sqrt{R\,Tex}$$

Where a, a' and b, b' and c, c' are constants depending on fabric type and finishing route

'STARFISH' MODELS

Step 3:

CALCULATE DIMENSIONS IN ANY STATE BY SCALING UP FROM THE REFERENCE STATE ACCORDING TO EITHER

(a) KNOWN SHRINKAGES, or

(b) KNOWN COURSES & WALES, or

(c) KNOWN WEIGHT & WIDTH

Diagram 12

COURSES & WALES CALCULATED FROM 'STARFISH' EQUATIONS

JET DYED & FINISHED INTERLOCK

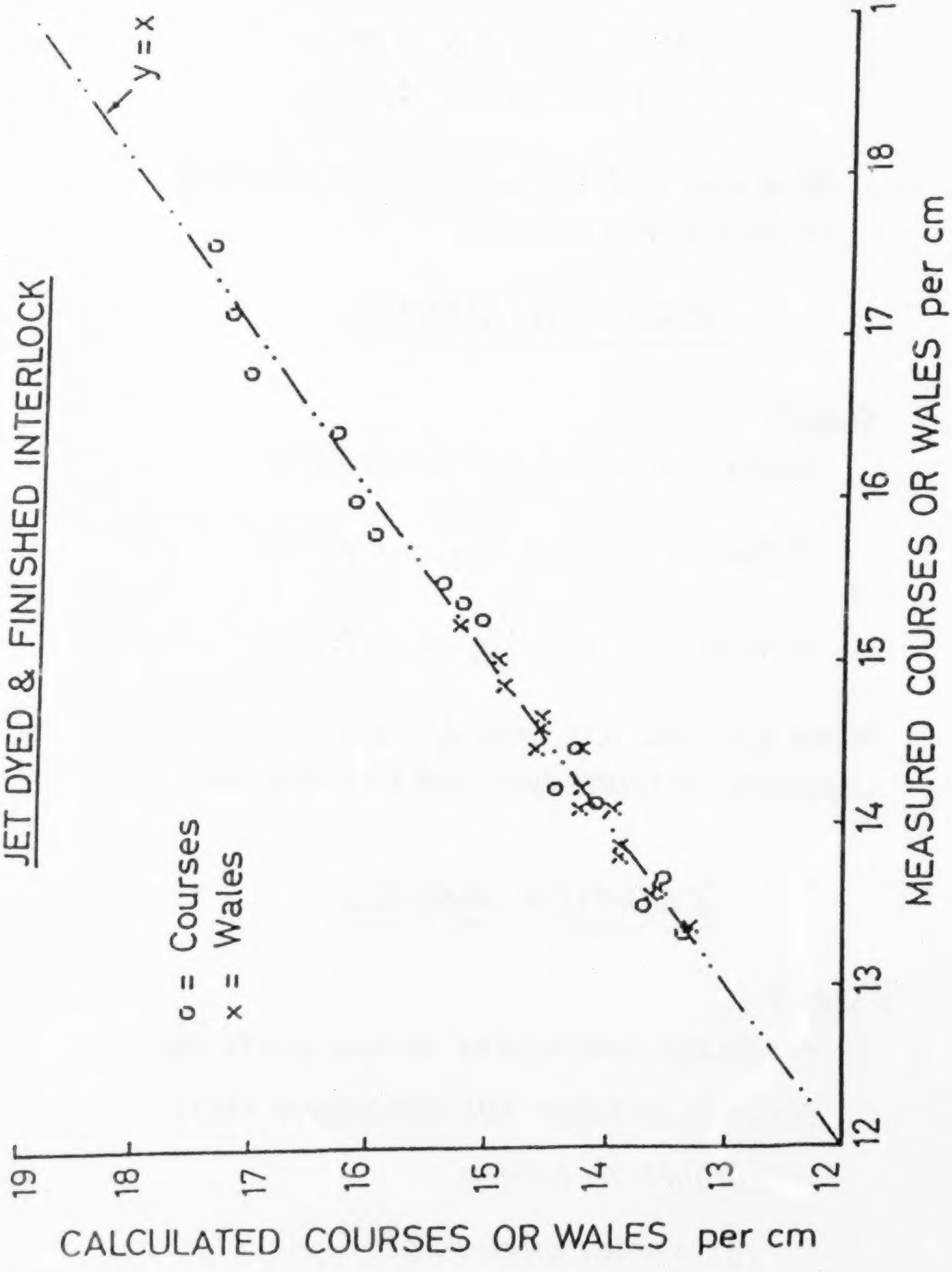
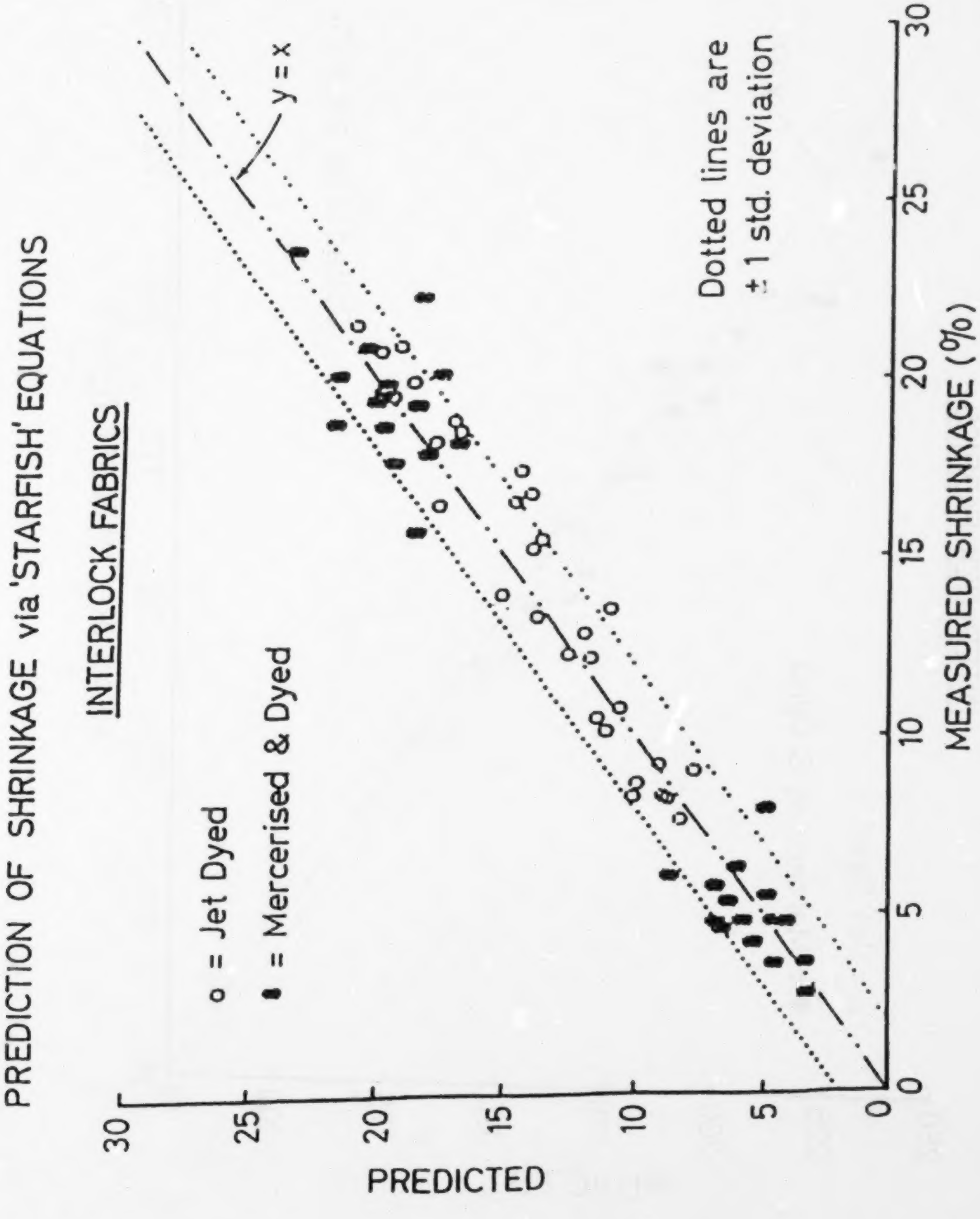


Diagram 13



PREDICTION OF SHRINKAGE via 'STARFISH' EQUATIONS

INTERLOCK FABRICS

Diagram 14

PREDICTION OF WEIGHT PER SQ. METRE via 'STARFISH' EQUATIONS

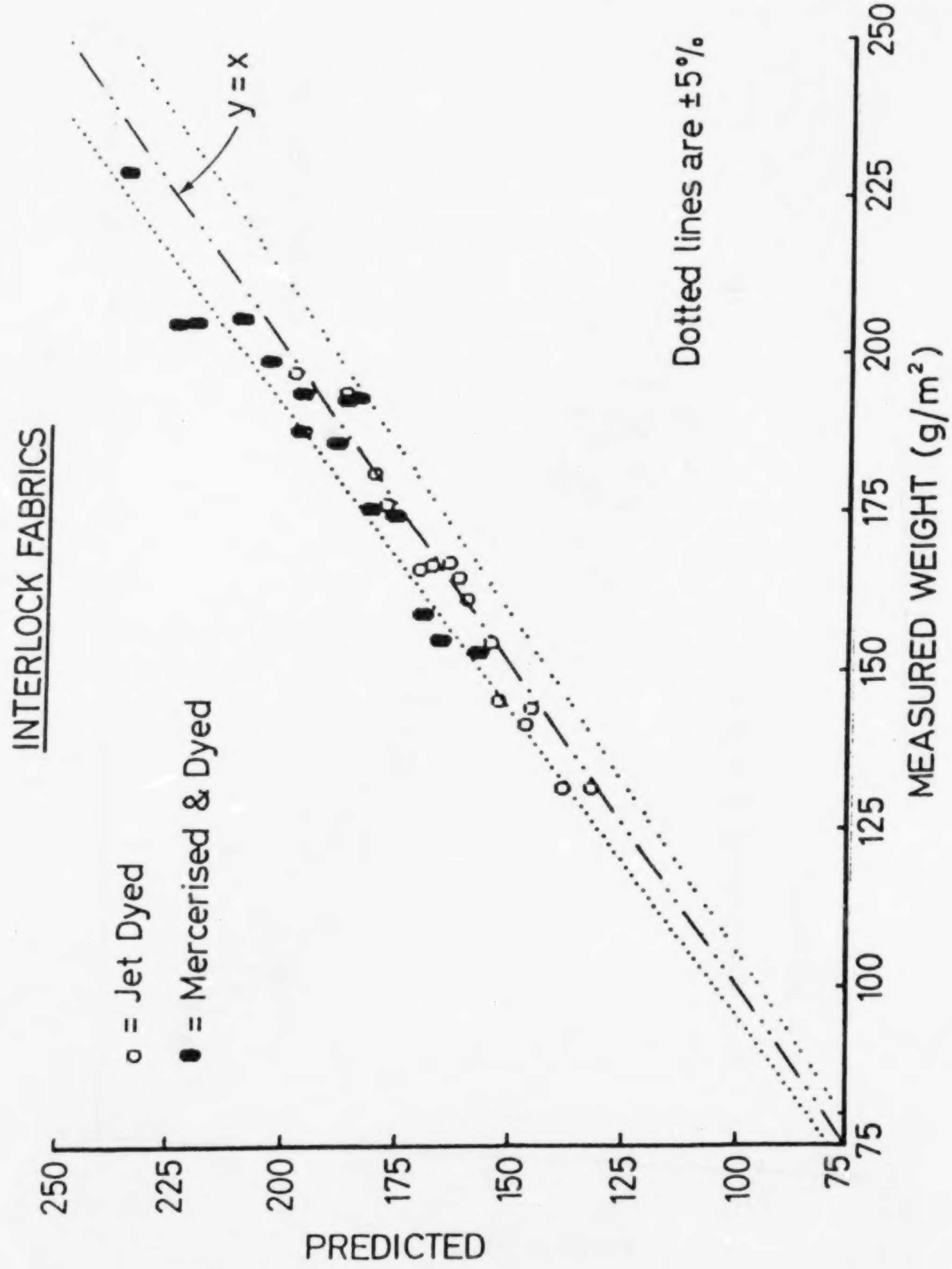


Diagram 15

CHECKING THE STARFISH MODELS IN PRODUCTION

DIMENSIONS IN THE REFERENCE STATE	INTERLOCK Ne 38 3·38 mm Continuous Bleach		1 × 1 RIB Ne 30 2·82 mm Winch Dye	
	Measured	Predicted	Measured	Predicted
YARN Ne	39·3 ± 1·0	38·6	31·2 ± 0·7	31·4
STITCH LENGTH mm	3·31 ± 0·06	3·32	2·75 ± 0·04	2·78
COURSES / 10cm	152 ± 3	149	184 ± 3	180
WALES / 10 cm	144 ± 5	145	114 ± 3	114
WEIGHT g/m^2	211 ± 5	213	210 ± 8	207

Diagram 16

CHECKING THE STARFISH MODELS IN PRODUCTION

DIMENSIONS AFTER FINISHING	INTERLOCK Ne 38 3·38 mm Continuous Bleach		1 × 1 RIB Ne 30 2·82 mm Winch Dye	
	Measured	Predicted	Measured	Predicted
YARN Ne	38·7 ± 0·9	38·3	31·2 ± 0·8	31·1
STITCH LENGTH mm	3·33 ± 0·05	3·31	2·77 ± 0·04	2·76
COURSES / 10 cm	127 ± 6	126	165 ± 4	163
WALES / 10 cm	123 ± 5	125	97 ± 3	97
WEIGHT g/m^2	158 ± 7	155	168 ± 9	165
% SHRINKAGE - LENGTH	16 ± 3	16	10 ± 2	9
- WIDTH	14 ± 2	14	14 ± 2	13

Diagram 17

STARFISH APPLICATIONS

* SET FINISHING TARGETS
* CHECK PRODUCT SPECIFICATIONS
* DEVELOP NEW PRODUCTS
* GUIDE NEW INVESTMENTS

Diagram 18

PRODUCT DEVELOPMENT FOR BODY-WIDTH FABRIC

PROPOSED END USE

PLAIN DYED SINGLE JERSEY T-SHIRTS

NEAREST CURRENT QUALITY

28g, 1404 NEEDLES,
MADE FROM Ne 36 at 2·70mm

JET DYED AND CALENDERED TO
FINISH AT 49cm

WEIGHT = 110 g/m^2

SHRINKAGE APPROX. 10% × 10%

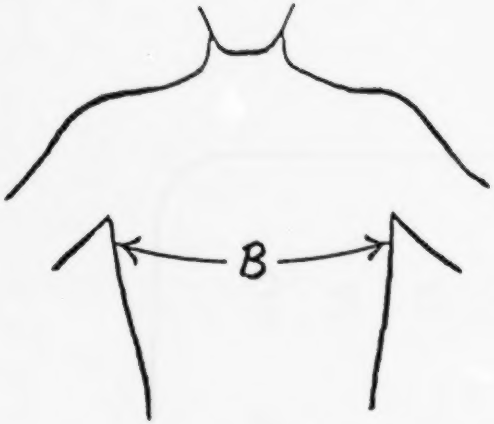
OBJECTIVES

- MAINTAIN APPROX. SAME FINISHED WEIGHT ($110\ g/m^2$)
- IMPROVE SHRINKAGES TO ABOUT 8 × 8
- OPTIMISE CONSTRUCTION AND FINISHED WIDTH
- IDENTIFY THE MOST SUITABLE KNITTING MACHINE

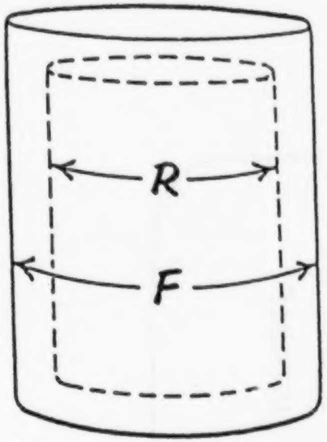
AVAILABLE MACHINES

	①	②	③
GAUGE	28	26	28
DIAMETER	16	18	20
NEEDLES	1404	1476	1512

Diagram 21



B = BODY WIDTH



F = FINISHED WIDTH
R = REFERENCE WIDTH (relaxed)

REFERENCE FIT = R/B

FOR A CLOSE FIT, R FIT IS LESS THAN 1·0
FOR A LOOSE FIT, R FIT IS GREATER THAN 1·0

Diagram 22

1. SELECT DESIRED REFERENCE FIT
2. CALCULATE TARGET REFERENCE WIDTH

   $$R_{WIDTH} = B_{WIDTH} \times R_{FIT}$$

3. CALCULATE REFERENCE WALES/cm via STARFISH
4. CALCULATE THEORETICAL NUMBER OF NEEDLES

   $$N = R_{WIDTH} \times 2 \times R_{WALES}$$

5. SELECT NEAREST AVAILABLE MACHINE
6. WORK STEPS 1 to 4 BACKWARDS TO OBTAIN ACTUAL FIT
7. IF THIS NOT SATISFACTORY, THEN FABRIC QUALITY MUST BE CHANGED, USING STARFISH TO FIND OPTIMUM STITCH LENGTH
8. CALCULATE ALL REFERENCE DIMENSIONS via STARFISH
9. CALCULATE ALL FINISHED DIMENSIONS BY BUILDING IN DESIRED/ACHIEVABLE SHRINKAGE LEVELS
10. CHECK THAT FINISHED WEIGHT (COST) IS ACCEPTABLE
11. IF NOT, FABRIC QUALITY MUST BE CHANGED
12. RUN SAMPLING TRIALS TO CONFIRM REFERENCE DIMENSIONS AND SHRINKAGES
13. MONITOR BULK PRODUCTION TO CONFIRM RESULTS OF SAMPLING TRIALS

KNITTING TARGETS

BODY WIDTH = 48·3 cm (38 inch chest)
TARGET REFERENCE FIT = 0·95
TARGET REFERENCE WIDTH = 45·8 cm

	CURRENT QUALITY	ALTERNATIVES 1	2	3
NEEDLES	1404	1404	1476	1512
ST. LENGTH	2·70	2·85	2·65	2·55
TIGHTNESS	15·0	14·2	15·3	15·9
R. WIDTH	44·1	45·7	45·8	45·8
R. FIT	0·91	0·946	0·950	0·950

Diagram 24

FINISHING TARGETS

	CURRENT QUALITY	STARFISH PREDICTIONS FOR ALTERNATIVES		
		1	2	3
COURSES / 10 cm	186	176	193	202
WALES / 10 cm	143	141	149	152
WEIGHT g/m^2	110	108	117	121
WIDTH cm	49	49·7	49·7	49·7
% SHRINKAGE				
– LENGTH	9·6	8·5	8·0	8·0
– WIDTH	10·0	8·0	7·8	8·0

DISCUSSION

MR. S. A. HEAP'S PAPER

Discussion following this final presentation of IIC's cotton knitting programme began, predictably, with questions concerning the availability of STARFISH for the knitting industries of countries other than the UK. It was rather difficult to provide a service at long distance, the speaker explained, and it would be hardly possible to introduce the model directly into a mill in Brazil or India, for instance from the UK. To facilitate dissemination of the data and know-how, IIC had therefore begun to establish a series of STARFISH user-centres in collaboration with suitable national research institutes. The experts in these centres would then provide a service to the local industries.

In principle, of course, it was possible for individual firms to supply data to IIC Manchester together with a complete description of how the fabric was made and finished. If the processing line and the fabric quality corresponded with the information in the model, then clearly a prediction could be given. On the other hand it would be embarrassing if more than a certain number of firms responded in this way. It was a question of time and manpower.

In response to further questioning the speaker explained the STARFISH model itself. It was a programme on a disc designed for a particular computer system. Several computer models had in fact been produced, some of which were still in a rough and ready state. The one which would be demonstrated was reasonably well developed and, under certain circumstances, could be operated by those with the necessary expertise and hardware.

The existing programme calculated forward from the knitting parameters and finishing route to the finished properties. Work was in progress on the reverse calculation which produced options for producing grey fabric.

The programme was in BASIC and it would be easy to adapt it to a personal computer. It required a capacity of about 35k. IIC had used a Tektronix computer simply because it was a good, general purpose scientific machine.

Asked if he would welcome a flow of data from mills that would like to participate, the speaker said he would, in principle, though it was not quite that simple - sampling, for instance, was part of the problem. Test data generated in one laboratory often was not quite the same as in another. That was an acceptable situation if one could establish what the difference was, why it occurred, how systematic it was and what the correction factors had to be. One solution was for the samples to be tested in Manchester but again it was a question of time and resources.

When one of the Brazilian delegates commented that it looked as if they would have to set up a national STARFISH programme in Brazil, the speaker agreed enthusiastically.

Since the programme was established on certain machine gauges and certain yarn counts, was there any possibility of establishing conditions for intermediate constructions? The speaker said 'yes'. A series of fabrics had been produced on 20 gauge interlock and another series on 28 gauge interlock using a particular finishing route. It was found that it was possible to combine the data from these in such a way that the performance of intermediate constructions could be predicted.

Another questioner asked if he was right in thinking that the first step for calculation must be to establish the K factor of the finishing line. The speaker said that that would indeed work as a stop-gap system. For every quality and every finishing route one could establish the K factors and it would work, though not if one wanted to process a very different quality down the same finishing route.

Asked what resources, personnel and financial input would be needed to set up a STARFISH satellite centre in Brazil, Mexico or India, the speaker said the first requirement was a testing laboratory, because the work would involve a lot of fabric testing on behalf of the people who would like to use the system. Possibly the IIC team in Manchester could be used as a guide for personnel requirements. The expertise and industry contacts would have to be built up gradually. It would certainly be feasible for such a new team to accept some of the load involved in developing the STARFISH system further.

Asked to give some indication of the profit possibilities for STARFISH, the speaker said it obviously varied with individual companies. Some users claimed that as a result of using STARFISH they had been able to get more garments out of a piece of fabric because they were finishing it to an appropriate size, and they could thus calculate how many thousands of pounds that represented. More stringent monitoring of stitch length was another example that had been given earlier - a 1% saving in yarn represented a tremendous amount of money even in a medium sized company.

In response to further questions, Mr. Heap said that pad-batch processing was not included in the programme and very little work had been done on carded yarns. However, it was expected that no large differences would be seen between combed yarns and carded yarns but that point could be checked, if necessary, with substantially less effort than had been expanded on the combed yarns.

Rotor yarns were another matter. They were becoming more important and could change the picture significantly, he suggested. They were already starting to enter the European knitgoods field and in the United States and Japan they were expanding their technical and economic horizons to ever finer counts. He thought rotor yarns would be a much more interesting and technically and economically useful area to study than carded yarns. Any other new spinning systems could be ignored for at least ten years, he suggested.

A second point was that there was definitely a need to examine more finishing routes. A fundamental weakness of the STARFISH system was that almost as soon as the effect of one finishing route had been quantified, another new machine would make its appearance, which might give a different result. So there was a constant need to keep abreast of new finishing techniques and new finishing machinery. An attempt had to be made to identify the key features of all those finishing techniques; e.g. to isolate what it was about a winch machine which made the processed fabric different from that treated in a jet, so that eventually one might even be able to predict how a new finishing route would perform simply by noting the components in that finishing route.

The same concept of distilling from what had already been collected in order to produce more general guidelines was extendable also to different fabric constructions. The mathematical analysis had to be pursued Mr. Heap believed, so that the equations could be unified across fabric types - interlock, rib, single jersey - and predictions could be made for a range of fabrics that might not even have been made before.

It should be remembered, too, that the large majority of IIC's work, and certainly the equations, were dependent upon the use of the five-cycle tumble drying test. Work was in progress to discover the relationships between the results of a tumble drying test and a line drying test as well as the difference between one cycle and five cycles. There was much more to be done to make the whole programme more applicable to the kind of specifications which were actually being written by retailers.

The cooperative programme between IIC and the Swedish Textile Institute was aimed at providing more data on the performance (especially extensibility and fit) of garments as compared to fabrics. No results had been included in the seminar papers because the work was very new and data were only just beginning to emerge. Possibly the data base would in future include population and sizing statistics so that when the fabric had been built on the STARFISH model it would be possible to go ahead and specify which sizes and population types were of interest, to isolate the target and garment type, and to design the garment as well as the fabric.

THE DYEING AND FINISHING OF COTTON KNITGOODS - THE BALANCE BETWEEN QUALITY AND COST

Mr. G.A. Richardson
Courtaulds Plc

1. INTRODUCTION

In comparison with the production of woven cotton cloths, which can be traced back many centuries, the history of knitted cotton is much more recent. Knitting itself is, of course, a much younger technology than weaving, and was miniscule in terms of volume of production until the middle of the present century.

The explosive growth of knitgoods production dating from that time was born of the demands for outlets from the rapidly growing synthetic fibres industry, and the consumer societies of the Western world, recovering after World War II, for "easy-care" clothing to match the increasing pace of their life-styles.

At that time, cotton played little or no part in the knitting boom, except in its traditional areas such as underwear. Two factors combined to change that situation.

Firstly, the "oil-crisis" of 1973/74 significantly increased the cost of production of oil-based synthetic fibres and the recession in the developed economies of the world which it brought about changed radically the attitude of the consumers of those countries.

Secondly, the adoption of cotton jeans and a knitted cotton T-shirt as the "uniform" of the younger generation across the world as a symbol of their unity against the establishment and its power politics which became synonymous with a youthful, casual, "with-it" attitude - whatever the age group of the wearer.

These two factors resulted in a tremendous growth in the demand for knitted cotton outerwear. It also resulted in a demand for better quality products than that traditionally produced for the underwear market. This trend has been augmented recently by the increased interest in physical fitness and the associated growth in active sportswear garments.

This growth in demand has continued almost unbroken through the recent recession in the world economy. It was clearly evident at the recent ITMA in Milan in October 1983, that almost all the major developments in the knitted fabric sector were associated with cotton-containing fabrics underlining their importance in the market. Some of these developments were aimed at processing cost reduction but the over-riding theme was quality improvement. Of course, any development which helps to reduce costs as well as improving quality, is doubly interesting and there were examples of this evident.

2. THE BALANCE BETWEEN QUALITY AND COST

There is a well quoted saying that "Quality Costs Money". That there is some truth in this, there is no doubt. However, it is important to achieve the right perspective in addressing the problem of how to achieve the right quality at an acceptable cost.

Firstly, the concept of quality has to be defined. Perhaps the best definition of quality is "conformance to requirements". There is no such thing as "good" or "bad" quality, it is not subjective, and there are no degrees of quality. Either a product or service conforms to requirements, or it does not. An example often quoted to illustrate this refers to two motor cars, a Rolls Royce and a Ford Escort, and the question "which is the quality car?" The answer is, of course, that both may or may not be, depending on whether or not they conform to all the requirements of a Rolls Royce or a Ford Escort.

To put this in context, the dyer and finisher of cotton knitgoods must be fully conversant with the requirements of his markets, and the performance standards he must achieve. It is in the area of performance standards that most problems arise. Most people understand and accept readily a particular requirement, but it is meaningless unless accompanied by a standard of performance.

For example, if your boss said to you "Come to work at 8.00 a.m.",you would probably accept that as a reasonable requirement. But if he followed that by adding, as a performance standard "Every day of the year" you would think it much less reasonable, and possibly too high a cost to your personal freedom and leisure time. Similar, the requirement of a dyer and finisher to produce wash fast dyeings on cotton knitgoods for T-shirts is reasonable, but possibly not if the performance standard was ISO4, Grade 5. The conclusion to be drawn from this is that in the quest to improve quality, it is very important to be absolutely clear of the requirements and performance standards to be met, otherwise you will finish up producing a Rolls Royce at a Rolls Royce cost but selling it at a Ford Escort price because that is what the customer wanted and expected.

Having defined the quality standards, in requirement and performance, the other side of the coin is to achieve these as efficiently as possible. Every new development aimed at reducing costs must be assessed also against its effect on quality. Failure to do this could have the opposite effect to that desired, i.e. decreased profitability by loss of market share. In order to target effort to the most important areas, it is essential to be familiar with the breakdown of costs. For the dyer and finisher of cotton knitgoods he should know not only the cost structure of dyeing and finishing but also how it contributes to the cost of the fabric and the garment.

From the data in Table I it can be clearly seen that the cost of fabric is very significant in the cost of the garment and that the cost of yarn and knitting is the dominant factor in the cost of fabric. A 10% saving in dyeing and finishing costs produces a 3.5% saving in fabric cost, and less than 2% in garment cost. Put another way, one could say that, "It is not worth spoiling the ship for a halfpenny worth of tar".

However, that is not to say that the search for reduction in costs in dyeing and finishing is not worthwhile. It is merely to point out that, for his own longer term success and indeed existence the dyer and finisher must balance all the requirements in arriving at decisions in adopting new processes and machinery. One aspect of quality that is often overlooked is service, in terms of quick delivery and short lead-times. In the volatile, fashion conscious apparel industry this is extremely important, and can have a marked effect on investment decisions in dyeing and finishing as we shall see later.

3. QUALITY AND COST IN THE DYEING AND FINISHING OF COTTON KNITGOODS - HOW CAN RECENT DEVELOPMENTS HELP?

If we refer back to Table I showing the cost structure for dyeing and finishing of a typical knitted cotton fabric, we can see that the main variable costs break down to three important, almost equal areas: dyes and chemicals, energy and water, and direct labour - each contributing about 20% of the total cost. The unit costs for these resources are also subject to continual increases, often above the general level of price inflation. It seems obvious, therefore, it is at these areas that developments to reduce costs should be targeted. It is no surprise, therefore, to find that in fact this has been the case.

In terms of product quality, it is helpful to review the major strengths and weaknesses of knitted cotton, noting the strengths or advantages which must be maintained, and the weaknesses which must be improved upon. There is no doubt that the popularity of knitted cotton garments is due to the comfort, and the feeling of being relaxed and at ease with the world, which that imparts. This feeling of comfort is due to a combination of the sympathetic properties of the cotton fibre and the knitted structure, amongst which are:-

a. a good moisture absorbency
b. good elasticity - stretch and recovery
c. soft, kind handle
d. good fit and drape properties

Likewise, the potential weaknesses are a combination of fibre and fabric properties. They are mostly manifested during or as a result of wash/-wear, and the most important are:-

a. a tendency to shrink
b. a tendency to show excessive surface hairiness
c. a tendency to appear dull and to lack crispness and brightness
d. a tendency to distort in shape

A knitted cotton textile should exhibit all of the strengths outlined above, and the weaknesses should be minimised with their relative importance depending on the particular end-use. That is to say, the improvement required in each property will depend on, for example, whether the garment is to be used for underwear or outerwear, or casual wear as opposed to formal wear.

With this background to quality and cost it is interesting to review process and machinery developments over the past few years, and the "state-of-the-art" as demonstrated at ITMA last October.

4. SPECIFIC DEVELOPMENTS IN THE DYEING AND FINISHING OF COTTON KNITGOODS AND HOW THESE CAN HELP ACHIEVE THE BALANCE BETWEEN QUALITY AND COST

4.1 Wet Processing

The main wet process is, of course, dyeing itself, but there are other wet processes ancillary to dyeing which are almost invariably carried out. These can be conveniently classified as preparation, or pre-treatments, designed to improve the quality of dyeing in the areas of levelness, reproducibility and brightness of shade, and post-treatments, primarily designed to improve the performance of the dyeing in colour-fastness.

The pre-treatments consist of scouring to remove oils, waxes and other soluble or emulsifiable contaminants on the fabric, and often bleaching to decolourise impurities not removed by scouring, and in the case of cotton, cotton seeds.

The post-treatments include washing to remove unfixed dyestuff and, in some cases, chemical treatments to improve the degree of fixation.

Traditionally, all these processes were carried out on the same machine, which, until 10 years ago would almost invariably have been a winch. This machine is relatively gentle in its action giving good quality fabrics. However, it suffers from major technical deficiencies, resulting in high intrinsic process costs in water, energy and chemicals and a high excess cost in reprocessing due to unlevel dyeing and poor reproducibility. This led to the development in the early 1970's of atmospheric pressure low liquor ratio versions of the high pressure jet machines used very successfully on knitted polyester fabrics, in which pumped circulation of the dyebath through a heat exchanger and reintroduction via a venturi-tube, or jet, through which the fabric was passing, gave much improved operating costs and more level and reproducible dyeings. Although the initial capital cost of these machines was many times that of a winch, the tremendous reduction in costs due to the much lower liquor ratio and re-dyeing levels, made them an attractive investment. Unfortunately, however, it was soon realised that on the relatively sensitive, spun cotton yarns, as opposed to the tough filament polyester yarns, the high velocity, high pressure liquor flow in the jet was causing an undue roughening of the fabric surface.

Rapid developments followed which took many forms, but all aimed at a much gentler action on the fabric with lower fabric running speeds, and suitable mechanical assistance to help transport the fabric around the machine, whilst maintaining the best features of the jet machines of low liquor ratio and good dye liquor - fabric interchange.

It was also realised that, whereas the machines were becoming "customised" towards dyeing processes, much of the time the fabric spent on the machine was in processes other than dyeing and that the features of the machine which made them efficient for dyeing, were not necessarily those which made them efficient for the other processes. Not only that, it was also evident that these other processes contained a higher element of standardisation, and could be readily considered for continuous operation. On the other hand, it was considered that, under certain circumstances, there was even a good case for dyeing by a continuous, or semi-continuous operation. The results of this evolution, which has occupied a remarkably short time-scale, are as follows:

4.1.1 Preparation Processes (Scouring, Bleaching) and After-Washing

The major development has been in moderately priced, continuous rope-treatment machines. These have evolved along parallel lines to dyeing machines, starting with continuous winches. However, these suffered from the same limitations and deficiencies of minimum liquor interchange; poor temperature control; high running costs for water, steam and chemicals, and difficulties in controlling fabric transport, requiring a high degree of operator supervision. Some of these problems were overcome by the introduction of the continuous jet machines, but treatment of the fabric is less gentle than the winch, and control over transport of the fabric is still difficult, particularly maintaining an even loading, and therefore processing time, in each of the storage compartments.

Two companies have developed interesting new machines, one following the conventional evolutionary path and one employing a completely new principle. The more conventional machines, the COLORADO from BRUCKNER was developed from their HASPELFLOW dyeing machines. The more revolutionary machine, the THIES RO, uses the principle of a peristaltic pump to give extremely intensive liquor interchange. The machines are illustrated in Figures 1 and 2, and their main features summarised in Table II.

The BRUCKNER machine is being used for chemical treatments, such as bleaching as well as scouring and washing. The THIES machine, in its basic form, is only suitable for some washing processes due to the very short dwell times possible. However, THIES are now developing a combination of storing compartments with the RO, which will widen the range of processes which can be carried out (Figure 3).

To illustrate the cost savings possible, Table III shows a comparison of consumptions of utilities and typical UK costs, for two-stage bleaching, cold chlorine plus hot peroxide, followed by optical brightening of knitted cotton on the winch and the COLORADO. Table IV shows a comparison for after washing a particularly difficult Reative Red shade on a jet dyeing machine and the COLORADO.

Obviously these costs would have to be adjusted depending on the particular location, but they do show the significant savings possible. Again, capital and financing costs would have to be assessed locally, depending on interest rates, write-off period, and the amount of production available on which to recover them.

On quality aspects, obviously the new machines could not be considered unless they achieved the desired levels of technical performance. The danger area is one of fabric appearance and aesthetics, and this requires evaluation over a wide range of fabrics. One potential problem on some fabrics, with the more conventional machines using a multi-mechanical squeezing, is rope creasing.

This is less of a problem with the RO machine since the fabric is cushioned by the liquor inside the rubber tubes during the squeezing action. However, there is a sort of "milling" effect which takes place, which might be desirable on some fabrics, but objectionable on others. In any case, it is true to say that the potential for cost savings has attracted a lot of interest in these, and other machines designed for similar purposes, and no doubt further refinements will be made to eliminate or minimise problems.

4.1.2 Dyeing

By far the most popular class of dyestuffs applied to knitted cotton fabrics are the Fibre Reactive. These give a wide range of shades untouched by any other class, particularly in the full/bright area, combined with good all round fastness, particularly wet fastness. They are therefore eminently suitable for the end-uses into which knitted cottons are directed. However, as a class, the Reactives tend to be expensive and application costs by exhaust techniques are also fairly high.

As outlined earlier, the major development in exhaust dyeing has been machines operating at lower liquor ratios which consume less water, energy and chemicals, and giving a more dependable quality of dyeing. It is also apparent that the classic "jet" dyeing machine and ultra-low liquor ratios, do not always produce the right quality product with sensitive knitted cotton fabrics. Recent developments have therefore concentrated on machines in which the main means of moving the fabric is a driven winch reel, with the fabric having a large arc of contact with the winch, and dye liquor interchange using the overflow principle rather than a jet. In addition, there has been a tendency to reduce the length and weight of fabric in the dyeing compartment with liquor ratios in the range of 8:1 to 12:1, and to reduce the running speed of the rope. In fact, a number of recent machines bear a remarkable basic similarity to the winch, with the addition of features from the jet dyeing machine developments to overcome the deficiencies of the winch. There are many machines now available in this category and the dyer has a wide choice of machines to suit individual requirements and fabrics.

Two machines which represent the different evolutionary hemispheres, with the traditional winch and jet lying at the poles, are the BRUCKNER HASPELFLOW and the SCHOLL SUBTILO (Figures 4 and 5).

The winch-like features of the HASPELFLOW are easily recognisable, as is the "jet" pedigree of the SUBTILO.

In selection of dyeing machines for knitted cotton, therefore, the potential buyer must be completely aware of the cost versus quality balance. Most dyehouses will have to process a range of fabrics from plain single jersey, through interlocks and ribs, to fleeces, terrys and velours.

To obtain the most effective balance, he is probably looking for the elusive "universal" dyeing machine that will give the optimum cost and quality result on all fabrics. However, he is unlikely to achieve this utopia and is more likely to have to compromise, and have a range of machines possibly from standard winches to ultra low-liquor ratio machines, to achieve the desired balance.

To illustrate the cost penalty of increasing liquor ratio, the data in Table V, although maybe a somewhat extreme case, does give an indication of the importance of controlling this factor.

No review of the dyeing of knitted cotton would be complete without mentioning the possibilities for application of alternative methods. Of these, cold pad-batch is currently the most important. That this does offer cost saving potential is irrefutable. However, it is also imperative that the prospective purchaser of pad-batch equipment is absolutely clear on the basis of the cost comparisons made, the technical and quality implications and the effect on the logistics of scheduling and operating his dyehouse.

Many cost comparisons of cold pad-batch against other methods have been made and published by dyestuff and machinery suppliers. Although the absolute figures vary, depending on the basis used for the costings, I believe that the situation reflected by the information in Table VI on the relative total costs of the basic processes of preparation, dyeing, after washing, hydroextraction and drying, are not far away from the truth under the conditions specified. The conclusions which can be drawn, under these conditions are:-

a. pad-batch dyeing shows cost savings against conventional batch processing at 20:1, but not at 8:1, when the fabric is prepared by conventional batch processing at either 20:1 or 8:1.

b. if preparation can be eliminated, pad-batch dyeing shows cost savings against conventional batch processing at both 20:1 and 8:1

c. the fixed costs of capital and finance require evaluation for the various processes and spreading over the available suitable production to calculate R.O.C.

d. the investment decision will depend on whether it is a replacement of not fully depreciated plant, or replacement of fully depreciated machines or a "green-field" situation.

In terms of quality, if we translate the 20:1 liquor ratio to a standard winch and the 8:1 liquor ratio to a modern low L.R. batch dyeing machine, the relative assessment in Table VII is typical. This might be somewhat simplistic, but I feel is representative of experience. The conclusion is that pad-batch dyeing can produce excellent quality fabrics but watch out for edge marks on tubular fabric, and it can be somewhat inflexible.

4.1.3 Mercerising

Much has also been said and written recently about this process; long-established on woven fabrics and yarn, as it relates to knitted cotton. The problems to be overcome have been two-fold. Firstly, the process technology and machinery developed for wovens could not be readily adapted to knits, particularly in the tubular form, due to the ease with which they extend under tension and form edge creases under pressure. That these technical problems have been largely overcome, particularly by machines such as that produced by Dornier, which uses adjustable "cigar" shaped expanders to control the tension and dimensions of the fabric during the critical stabilisation part of the process (Figure 5) is evident by the numbers sold.

The second problem has been largely commercial. The quality improvements on mercerising are indisputable and well-known, as is the improved dyeability. However, unlike woven cloths, large irreversible changes in fabric geometry and construction take place, which result in a completely different product. In particular, most knitted cotton fabrics subjected to mercerisation by the now normally accepted methods, will finish significantly narrower, somewhat longer and heavier (weight per unit area), than the same fabric conventionally finished.

The use of the IIC STARFISH data bank has proved valuable in engineering fabrics, having the desired final properties after mercerisation, although further data in relating different process conditions to final fabric properties is still required. To these fabric design problems, can be added the problem of recouping the extra processing costs in markets where mercerised fabrics are not the norm. In this context, the situation is made more difficult by the fact that mercerising machinery is not readily adaptable to other processes so that the fixed costs cannot be spread over other production if the market for mercerised fabrics is overestimated. It is also dangerous to assume that process costs will be offset by dyestuff savings, since the market for mercerised fabrics may demand shades unobtainable in any other way.

Before entering this field, it is therefore essential to assess the market requirements carefully, both in terms of potential volume and the premium price likely to be obtained. A primary factor in assessing this is knowledge of the variable costs of mercerising. This is largely independent of the type of equipment used, except in the areas of the presence or absence of recovery systems for chemicals and energy, and labour costs depending upon the production rate. Table VIII shows typical costs per Kg, both variable and fixed, for machines of different production rates and capital cost.

In this case, machine B with the higher production rate would give a lower unit cost of production above about 400 tonnes per annum production, as can be seen from a graph of the data in Figure 7. However, it is unlikely ever to show a better return on capital than machine A. Also from the graph in Figure 7, the profit at various levels of market price and volume can be read off. For example, a market premium of 30p per Kg and a volume of 100 tonnes per annum will not show a profit with either machine. However, an increase in volume to 200 tonnes per annum would show a profit of 5.9p and 3.75p per Kg with machines A and B respectively, and at 400 tonnes, both machines would show a profit of 10p per Kg.

4.2 Finishing

Although this paper has dealt mainly with wet processing, it would not be complete without a short review on finishing. The main problem which pre-occupies most finishers of cotton knitgoods is how to control residual shrinkage values. Unlike most synthetic fibres, cotton cannot be stabilised by "setting", i.e. the breaking and reforming of intermolecular bonds by simple methods, such as heating and cooling. The main mechanism of shrinkage in knitted cotton is change in the shape of the knitted loop structure, which is deformed during processing from its relaxed, regular, rounded shape, to an elongated, unstable state. During wash/wear, the loops tend to revert back to their stable, relaxed shape, giving rise to garment shrinkage, particularly in the length direction.

In order to minimise the shrinkage problem to the consumer, much effort has been directed at methods of pre-shrinking the fabric during finishing. As in other areas of technology in processing cotton knits, the first developments to solve this problem were adaptations of methods applied to woven fabrics, particularly the processes known as compressive shrinkage. Unfortunately, this involves the use of fairly high pressure on the fabric whilst the fibres are "sensitised" by heat and moisture, giving an adverse effect on fabric aesthetics, particularly loft, handle and surface appearance.

Recent developments have centred around other methods of applying the mechanical energy to pre-shrink the loop structure.

It was known from stenter processing technology of open-width fabrics that the length could be reduced on a stenter frame if the width of the cloth was gradually increased whilst overfeeding in the length, particularly if the fabric contained a reasonable amount of moisture or other lubricant to facilitate the movement of yarns. This led to the development of the so-called "wet compactors" to simulate this process in tubular form. The design of these machines vary in detail, but all include a special stretcher frame with the ability to extend the fabric in width whilst overfeeding the length. In some machines, the wet compaction is achieved whilst the fabric is saturated with water, whilst in others it is done after hydroextraction to a moisture content of about 55-65%. It is normal to overstretch the width of the fabric, i.e. in excess of the finished width, to a degree depending on fabric structure, single jersey rib, interlock, etc. to ensure that the maximum amount of length overfeed can be absorbed. After this process, the loop structure is somewhat over-compacted in length and over-extended in width. To apply the final correction, the fabric is then dried in as tensionless a state as possible, when the width shrinks to just below the final finished width and the length extends slightly.

Another method recently employed to pre-relax the fabric is based on tumble drying. It has long been known that the most effective way of fully relaxing knitted cotton is to wet-out and tumble dry. In fact it has been the increasing use of tumble dryers on the domestic scene in the developed countries which has put further emphasis on pre-relaxed fabrics. The conventional rotating drum industrial tumblers used traditionally in the garment finishing and laundry industries were found to be far too slow and unproductive for large-scale fabric finishing operations. Developments have therefore been directed at continuous tumblers and relaxing dryers. These are generally now of the endless conveyor band type, with the band produced from an open mesh, either of stainless steel, or more commonly, of a temperature resistant synthetic fibre composite (e.g. glass fibre reinforced polyester). The fabric is overfed onto the band and agitated either by vibration of the band or by discontinuous hot air jets, or a combination of both. In order to keep the fabric under control through the dryer, most designs now have double endless mesh bands, with the fabric travelling in the gap between them.

The use of such dryers is becoming increasingly more common and there is a wide variety of machines to choose from, all differing in points of detail, but all aiming towards the same objective. The main problems encountered with these machines is that the amount of mechanical tumbling action which a fabric can withstand varies from fabric to fabric before it becomes excessively "hairy" and the drying efficiency tends to be lower than conventional dryers. In order to minimise these problems, a combination of wet compacting, followed by pre-drying on a tensionless high efficiency dryer (e.g. drum) to approximately 20-30% moisture content and finally completion of drying and relaxing on a continuous tumbler or high relaxation dryer, is the optimum processing route. This new type of dryer includes:-

- Babcock "Aerovar"
- Bruckner "Witro"
- Kiefer "Rotoswing"
- Ruckh HDT 2000
- Passat "Air Shrinker"
- MTM-Obermaier "Shrink Tunnel"
- Santex "Santashrink"
- Alea CA80
- Fleissner Vibrating Conveyor Dryer

5. SUMMARY AND CONCLUSIONS

Today, the dyer and finisher of cotton knitgoods must be intimately aware of the requirements in terms of quality and standards of performance demanded by the markets he is serving. At the same time, he must also be ever conscious of the cost structures of his own business, and also of the wider industry of which he is a part in order to achieve the correct balance of cost and quality. To strike this correct balance is not easy with so many seemingly conflicting factors. However, if all the factors involved are carefully investigated and evaluated, there are many opportunities available in which to invest in both process and machinery technology, to help him achieve his objectives of a successful and lasting business.

TABLE I

BREAKDOWN OF PRODUCTION COSTS FOR A TYPICAL KNITTED COTTON TEXTILE

DYEING AND FINISHING	% OF PRODUCTION COST
Dyes and chemicals	22
Energy	15
Water/effluent	5
Labour - direct	19
- indirect	10
Other - mainly fixed	29
	100

FABRIC	
Yarn	50
Knitting	15
Dyeing and finishing	35
	100

GARMENT	
Fabric	54
Cutting	9
Making-up	31
Trimming/Packaging	6
	100

TABLE II

MAIN FEATURES OF TWO NEWLY DEVELOPED MACHINES FOR CONTINUOUS WET TREATMENT IN ROPE FORM

BRUCKNER COLORADO	THIES RO
Variable dwell time depending on loading of compartments and fabric speed. Gentle action-overflow. Improved liquor interchange by squeezing with soft air-filled tyres between each compartment.	Very short treatment time with extremely intensive liquor interchange. Trouble free fabric transport - no storage compartments.
Trouble free fabric transport - plaiting action of overflow pipes and automatic control of fabric level (variable) in each compartment.	No individual heating - external heated feed tanks. External storage compartments for stages of process requiring dwell time.
Easy loading. Easy interchange of coupling of compartments for various processes.	Easy and rapid threading up. Easy interchange of coupling of tubes.
Individual compartment heating/temperature control. Maximum $\Delta t = +30^{\circ}C$ adjacent compartments.	

Both machines have counterflow facility and can be easily connected to effluent heat recovery.

TABLE III

CONSUMPTIONS AND COSTS OF UTILITIES FOR BLEACHING AND OPTICALLY BRIGHTENING KNITTED COTTON

	WINCH		COLORADO	
	Consumption Per Kg	Cost Per Kg P	Consumption Per Kg	Cost Per Kg P
Water litres	103	3.61	15	0.53
Steam Kg	8.30	8.30	1.70	1.70
Power Kwh	0.03	0.10	0.10	0.32
Labour man mins	0.69	4.47	0.40	2.67
Chemicals		8.10		10.54
TOTAL		24.50		15.76

NOTES

WINCH - Average batch weight 215 kg

Liquor ratio 15.8:1, 6.5 fills

5 machines per 2 operators, £4.00 per man hour

Total cycle time 6 hours

Steam consumption calculated from bath volume (3400 litres), temperature rises and holding times

Chemicals from production recipes

COLORADO - Production rate 300 Kg per hour (at 75% efficiency)

2 operators, £4.00 per man hour

Water consumption 4500 litres per hour (Bruckner)

Steam consumption calculated from number of compartments, liquor volume of each compartment and temperature rise, for each process

Chemicals from trials carried out by Chemische Fabrik Tubingen

UNIT COSTS OF UTILITIES

Water (including effluent charges)	£ 0.35 per cu.m.
Steam (fuel costs only, 3500 sec. oil)	£10.00 per tonne
Power	£ 0.032 per kwh

TABLE IV

CONSUMPTION AND COSTS OF UTILITIES FOR AFTERWASHING REACTIVE DYED KNITTED COTTON

	LOW LIQUOR RATIO JET		COLORADO	
	Consumption Per Kg	Cost p Per Kg	Consumption Per Kg	Cost p Per Kg
Water litres	100	3.50	38	1.33
Steam Kg	5.54	5.54	2.10	2.10
Power Kwh	0.12	0.38	0.07	0.22
TOTAL		9.42		3.65

NOTES

SHADE	Bright, full red based on Procion HE-3B and Procion Yellow HE-4R
WATER	Consumptions measured via water meter.
STEAM	Consumptions calculated. Integral effluent heat recovery on Colorado producing water at 60°C.
POWER	Consumptions calculated by 60% of installed power and running times.

PROCESS

LOW LIQUOR RATIO JET

Batch weight 200 kg	Production 250 kg/hour
Bath volume 2500 litres	5000 litres per hour
2 baths $\Delta t = 85^\circ C$	2 rinses 1 x 60°C
1 bath $\Delta t = 50^\circ C$	1 x cold
5 baths cold	on jet after dyeing
	$\Delta t = 35^\circ C$ ($60^\circ C \rightarrow 95^\circ C$)

UTILITIES UNIT COST

Water/effluent	£ 0.35 per cu.m.
Steam (fuel cost)	£10.00 per tonne
Power	£ 0.032 per kwh

TABLE V

VARIATION IN COSTS WITH LIQUOR RATIO FOR PREPARATION, DYEING WITH REACTIVE DYESTUFFS TO A BRIGHT, MEDIUM RED SHADE AND AFTERTREATMENT OF A KNITTED COTTON FABRIC

PROCESS

- Pre-scour and bleach
- Dye
- Wash-off
- Soften

BASIS OF CALCULATIONS

Consumptions

- Water - 17 baths (including 4 cold running rinses = 8 baths)
- Steam - calculated from number of baths, Δt, and time at temperature

No. of baths	Δt
3	90
1	75
1	60
1	50
2	40
1	15

- Chemicals - calculated from standard recipes for pre-scour and bleach (peroxide) and softening.

Dyeing: 80g/l Salt
10g/l Soda Ash

Dyestuff not included

UNIT COSTS

- Water/effluent	£ 0.35 per cu.m.
- Steam	£10.00 per tonne
- Chemicals	UK bulk purchase prices

TABLE V cont'd

	LIQUOR RATIO				
	8 : 1	10 : 1	12 : 1	14 : 1	20 : 1
Consumptions/kg					
Water litres	136	170	204	238	340
Steam Kg	7.6	9.5	11.4	13.3	19.0
Costs/kg					
Water	4.76	5.95	7.14	8.33	11.90
Steam	7.60	9.50	11.40	13.30	19.00
Chemicals	16.28	18.27	20.26	22.25	28.22
TOTAL	28.64	33.72	38.80	43.88	59.12

If graphed, the cost data would give a straight line against liquor ratio, with a slope of 2.54 pence per Kg per unit of liquor ratio, and an intercept on the cost axis of about 8.5p/Kg, representing chemicals based on fabric weight and not liquor volume.

TABLE VI

RELATIVE COSTS OF VARIOUS PROCESSING METHODS FOR KNITTED COTTON FABRICS

	Conventional Batch Processing at		PAD BATCH-A			PAD BATCH-B		
			Greige	Prepared		Greige	Prepared	
Liquor Ratio	20:1	8:1		20:1	8:1		20:1	8:1
Relative Cost	1.00	0.81	0.77	0.90	0.85	0.71	0.85	0.80

CONDITIONS

- Fabric	100% cotton, 200g/running metre
- Shade	Navy, 5% dyestuff. Procion MX dyes
- Batch size	Conventional Batch Processing 300 Kg
	Pad batch A - 300 Kg, 1500 m
	B - 1800 Kg, 9000 m
- Batch times	Conventional batch processing - 10 hours
	Pad-batch - 40m/min + 30 mins down time

PROCESSES

- Conventional batch processing
- Scour, dye, wash, hydroextract, dry
- Pad-batch
- Greige-pad batch, beam wash, hydroextract, dry
- Prepared - scour (20:1 and 8:1), hydroextract, dry
  pad batch, beam wash, hydroextract, dry

COSTS

- Labour, steam, water and effluent, power dyes and chemicals.
- It has been assumed that padding on greige fabric will require 10% more dyestuff than padding prepared fabric and that in both padding cases 30 litres of liquor are wasted at the end of the run.

TABLE VII

RELATIVE ASSESSMENT OF QUALITY RATING OF KNITTED COTTON FABRICS DYED BY VARIOUS METHODS

QUALITY	WINCH	MODERN LOW L. R.	PAD BATCH
Levelness of Dyeing	Moderate	Good	Excellent
Shade reproducibility	Moderate	Good	Excellent
Chance of creasing	High	Medium	Low
Surface appearance	Good	Variable	Excellent
Chance of edge marks	Low	Low	High (on tubular)
Handle	Good	Good	Good
Service*			
- one shade	Moderate	Good	Excellent
- a few shades	Moderate	Good	Moderate
- many shades	Moderate	Good	Poor

* Defined as the ability to produce quality fabric, in quantity, quickly

TABLE VIII

COSTS PER KG FOR VARIABLE AND FIXED COSTS FOR MERCERISING ON TWO DIFFERENT MACHINES AT DIFFERENT ANNUAL PRODUCTION

ANNUAL PRODUCTION TONNES	COST PER KG - PENCE					
	MACHINE A			MACHINE B		
	Variable Costs	Fixed Costs	Total	Variable Costs	Fixed Costs	Total
50	14.00	40.38	54.38	12.00	57.00	69.00
100	14.00	20.19	34.19	12.00	28.50	40.50
200	14.00	10.09	24.09	12.00	14.25	26.25
500	14.00	4.04	18.04	12.00	5.70	17.70
1000	14.00	2.02	16.02	12.00	2.35	14.35

MACHINE A - 250 Kg per hour, Capital cost £ 85,000

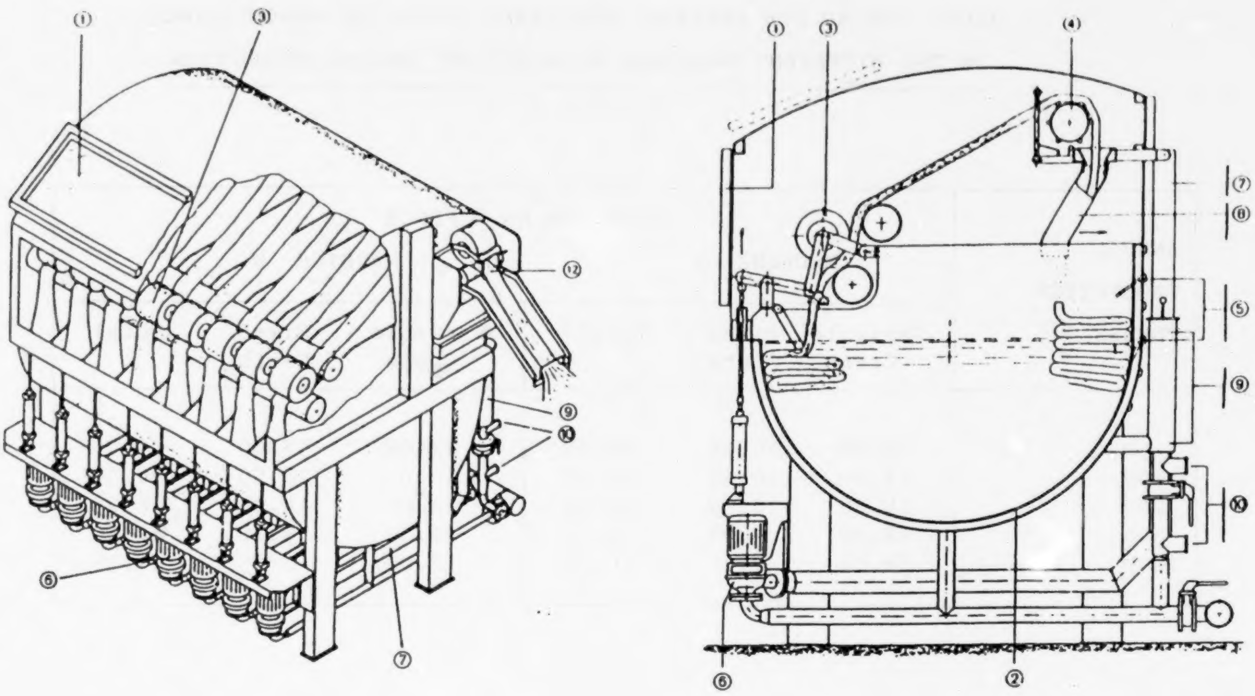
MACHINE B - 500 Kg per hour, Capital cost £120,000

LABOUR COSTS - £10.00 per hour for each machine

FIXED COSTS - 20% of capital cost + 7½% of half capital cost per annum

Brücker "Colorado"

FIGURE 1



① Pneumatically operated door over the entire machine width with large glass inspection windows.

② Plastic slat liner guarantees smooth fabric transport.

③ Individual squeezing wheels filled with compressed air mould themselves to the fabric rope.

④ Reel for fabric transport.

⑤ Adjustable sensors which monitor the required chamber loading and make any necessary corrections by automatic control.

⑥ Circulating pump for each compartment.

⑦ Heat exchanger with temperature control, for each compartment.

⑧ Reciprocating fabric transportation tube, for each compartment.

⑨ Infinite adjustment of bath level (adjustable overflow).

⑩ Valve with quick-fitting, interchangeable connections to enable bath drainage, liquor inflow, liquor metering or liquor flow from section to section.

⑪ Counterflow heat exchanger for preheating the fresh water and for cooling the effluent.

⑫ Fabric feeding from the side.

Thies Rope Washing Machine "Ro-12" **FIGURE 2**

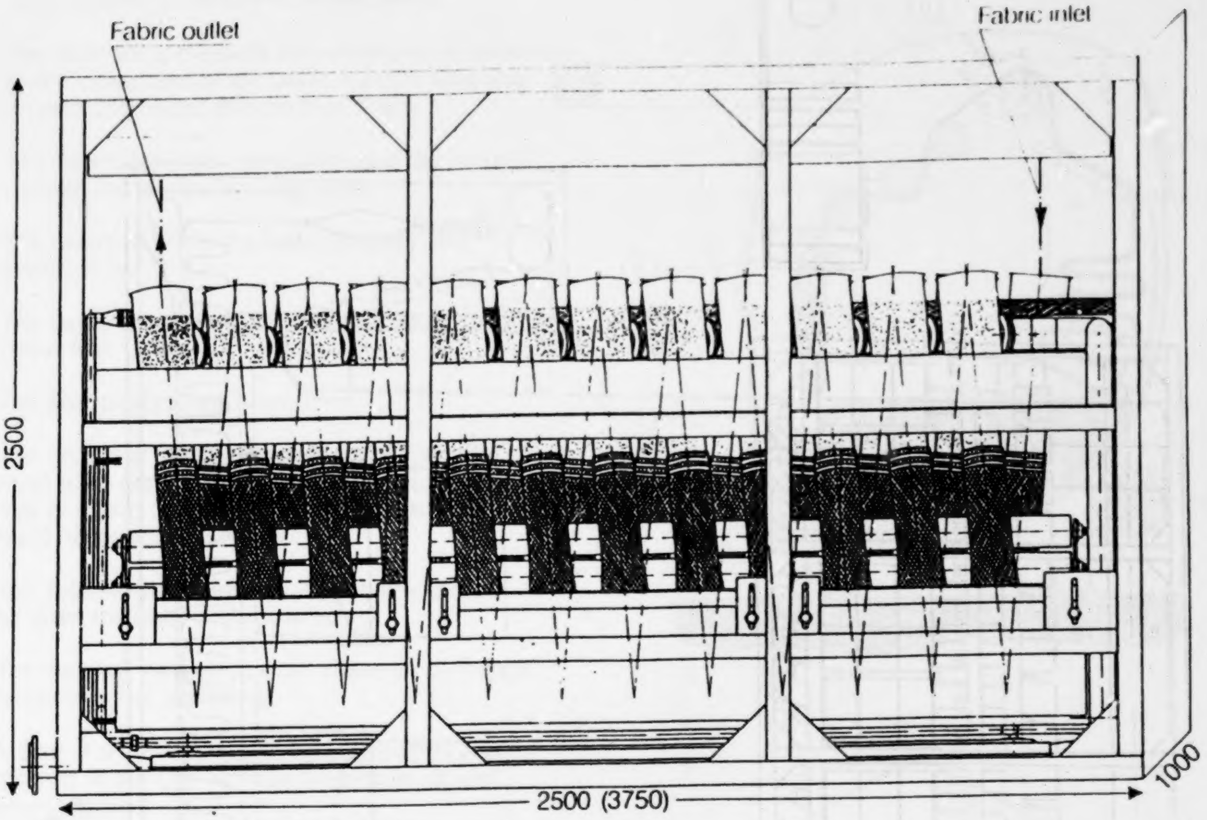

Fabric outlet
Fabric inlet
2500
2500 (3750)
1000

Diagram of afterwashing dyed fabrics

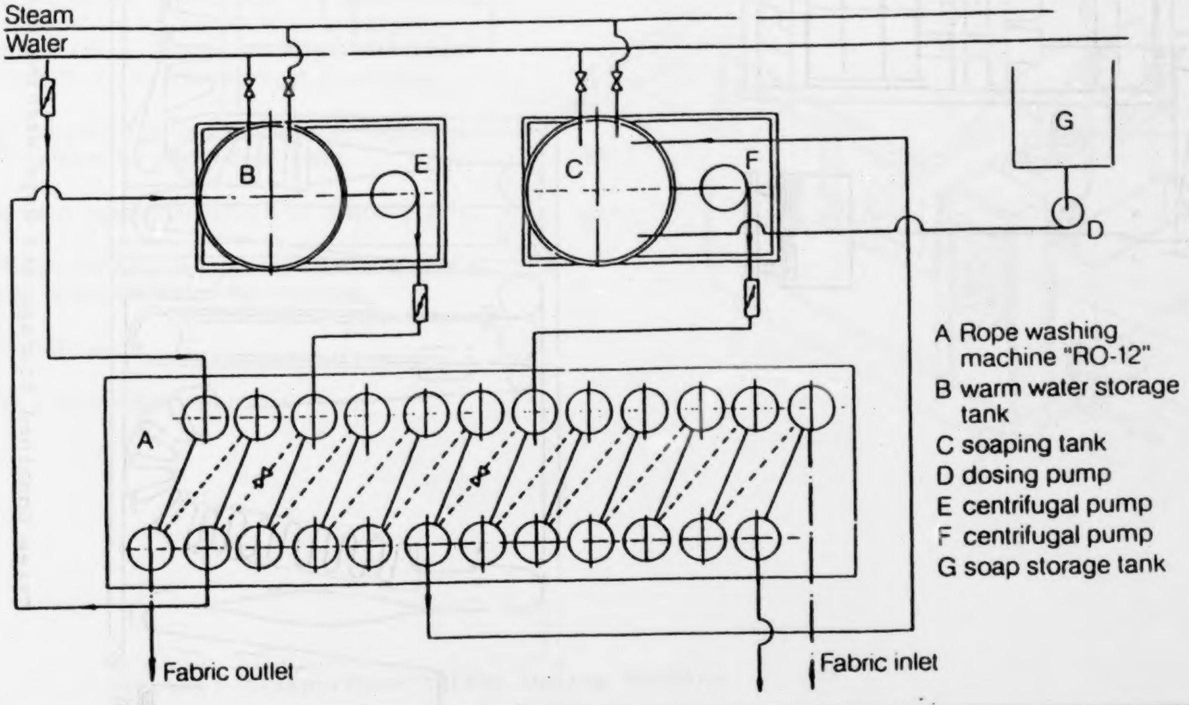
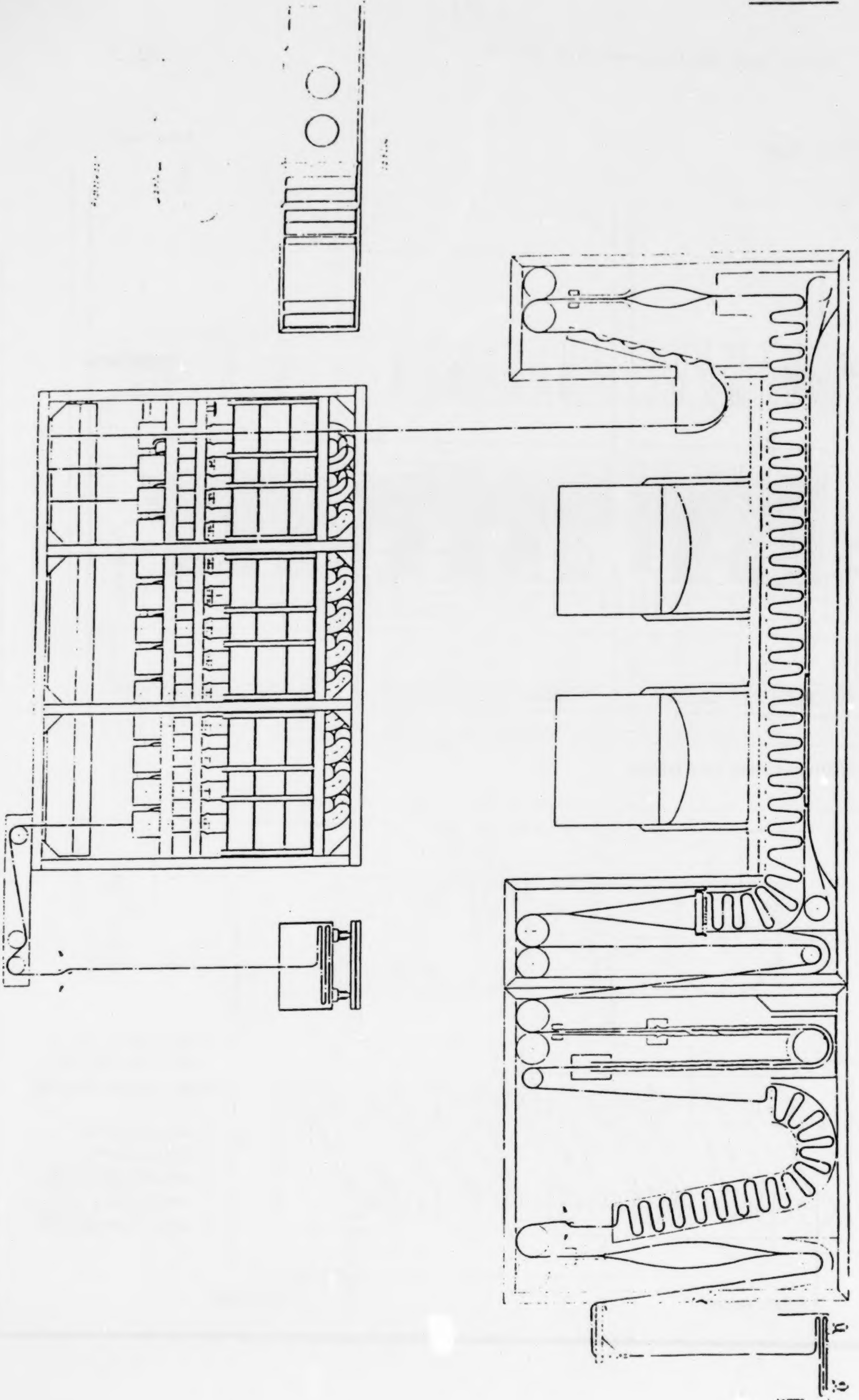

Steam
Water
B
E
C
F
G
D
A
Fabric outlet
Fabric inlet
A Rope washing machine "RO-12"
B warm water storage tank
C soaping tank
D dosing pump
E centrifugal pump
F centrifugal pump
G soap storage tank

FIGURE 3



Thies Combined Storage and Rope Washing System

16 distinguishing features of the HASPELFLOW B

① The specially shaped "J" box holds 100 to 120 kilos of fabric in either one or two ropes.

② The slats lining the beck offer minimum resistance to the movement of the fabric, thereby ensuring a perfect transport through the "J" box.

③ The driven conveyor rollers transport the fabric through the air space of the beck.

④ The plaiter deposits the rope precisely and evenly in the "J" box.

⑤ The pump provides for an intensive liquor circulation.

⑥ The filter protects the pump.

⑦ The design of the heat exchanger is such that there is no restriction of the heating capacity due to soiling by lint etc. in the liquor, so that rapid heating-up is ensured.

⑧ The Tublow system inflates the fabric rope with air (from the beck atmosphere).

⑨ The overflow weir enables an intensive exchange between liquor and fabric.

⑩ A door at the front enables easy operation and hatches at the rear facilitate inspection as and when required.

⑪ The preparation tank is fitted in a space-saving arrangement and, in spite of its rectangular shape, it effects thorough mixing of the liquor by means of a horizontal direct steam pipe.

⑫ High pressure fan for supplying the Tublow unit with air from the beck atmosphere.

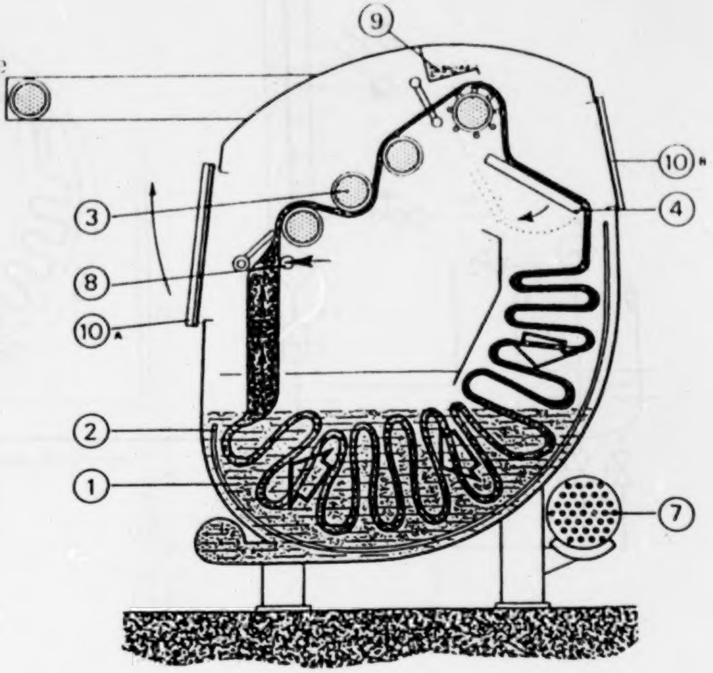
⑬ Steplessly adjustable drive with remote control.

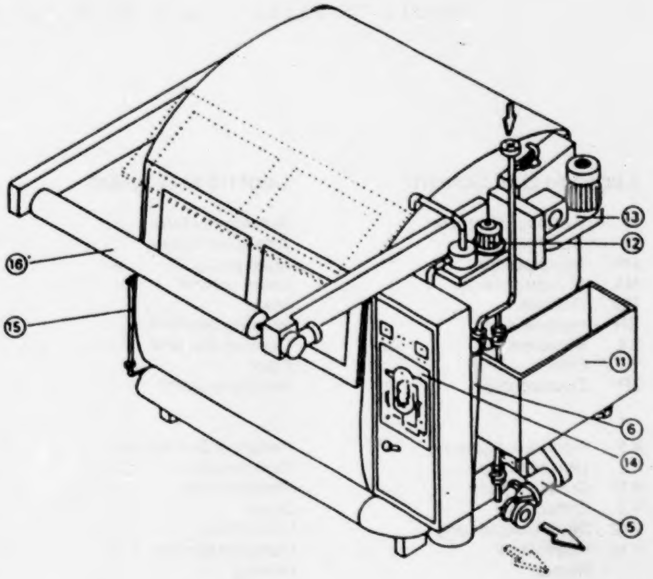
⑭ Stainless steel control cabinet fitted in a space-saving arrangement on the machine.

⑮ Level indicator.

⑯ Plaiting roller with independent drive.

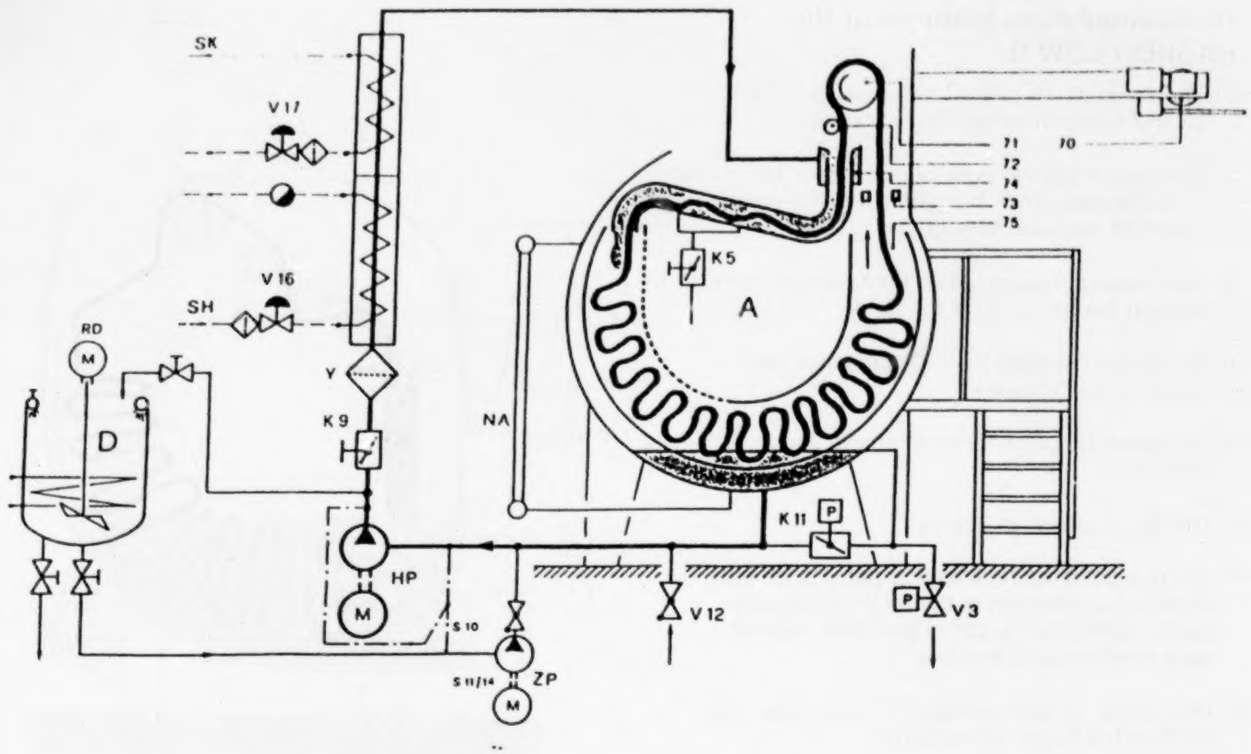
FIGURE 4





Brückner "Haspelflow" Piece Dyeing Machine

FIGURE 5



Scholl "Subtilo" Low L.R. Piece Dyeing Machine

	Legende zum Schema	Legend to diagram	Légende du schéma	Leyenda del esquema
A	Autoklav / Behälter	Autoklave / tank	Autoclave / récipient	Autoclave / Recipiente
D	Abrufgefäss	Additions vessel	Récipient d'alimentation	Recipiente de alimentación
HP	Hauptpumpe	Main pump	Pompe principale	Bomba principal
NA	Niveauanzeiger	Level control	Niveau	Nivel
RD	Rührwerk	Mixer	Agitateur	Agitador
SH	Heizelement	Heating element	Elément chauffage	Elemento calentamiento
SK	Kühlelement	Cooling element	Elément refroidissement	Elemento enfriamiento
Y	Filter	Filter	Filtre	Filtro
ZP	Zusetzpumpe	Additions pump	Pompe d'addition	Bomba de adiciones
K 5	Flottenrückführung	Return of dye liquor	Retour du bain	Regreso del baño
K 9	Drosselklappe	Throttle valve	Papillon	Válvula mariposa
K 11	Drosselklappe	Throttle valve	Papillon	Válvula mariposa
V 3	Entleerung	Drain	Vidange	Vaciado
V 12	Direkteinspeisung	Direct feed	Alimentation directe	Válvula alimentación directa
V 16	Regelventil Heizen	Modulating valve heating	Soupape de réglage de chauffage	Válvula reguladora calentamiento
V 17	Regelventil Kühlen	Modulating valve cooling	Soupape de réglage de refroidissement	Válvula reguladora enfriamiento
70	Ein- und Ausfahrhaspel	Loading and unloading winch	Tourniquet de chargement et de dechargement	Aspa de carga y descarga
71	Haupthaspel	Main winch	Tourniquet principal	Aspa principal
72	Warenlaufkontrolle	Fabric running control	Contrôle de la marche de la matière	Control de la marcha de la tela
73	Nahtsucheinrichtung	Seam tracing device	Système cherche-couture	Dispositivo busca-costuras
74	Flottenbeschleunigungs-vorrichtung	Dye liquor acceleration device	Dispositif d'accélération du bain	Dispositivo de aceleración del baño
75	Warenspeicher	Fabric storing chamber	Accumulateur de matière	Acumulador de material

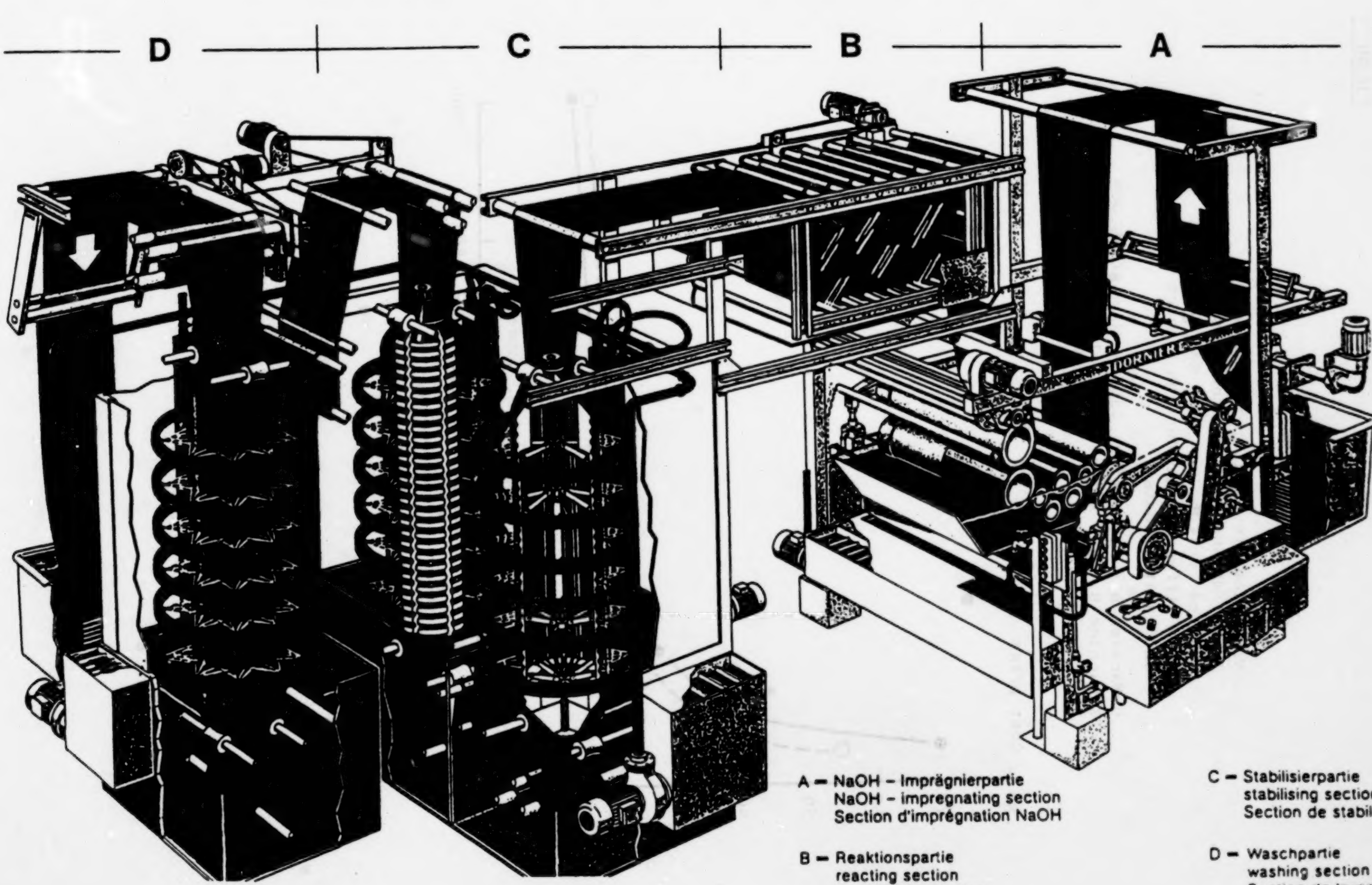
FIGURE 6

DORNIER

Schlauchwirkwaren –
Mercerisieranlage

Mercerizing range
for tubular knit goods

Installation de mercerisage
de tricots tubulaires



A – NaOH – Imprägnierpartie
NaOH – impregnating section
Section d'imprégnation NaOH

B – Reaktionspartie
reacting section
Section de réaction

C – Stabilisierpartie
stabilising section
Section de stabilisation

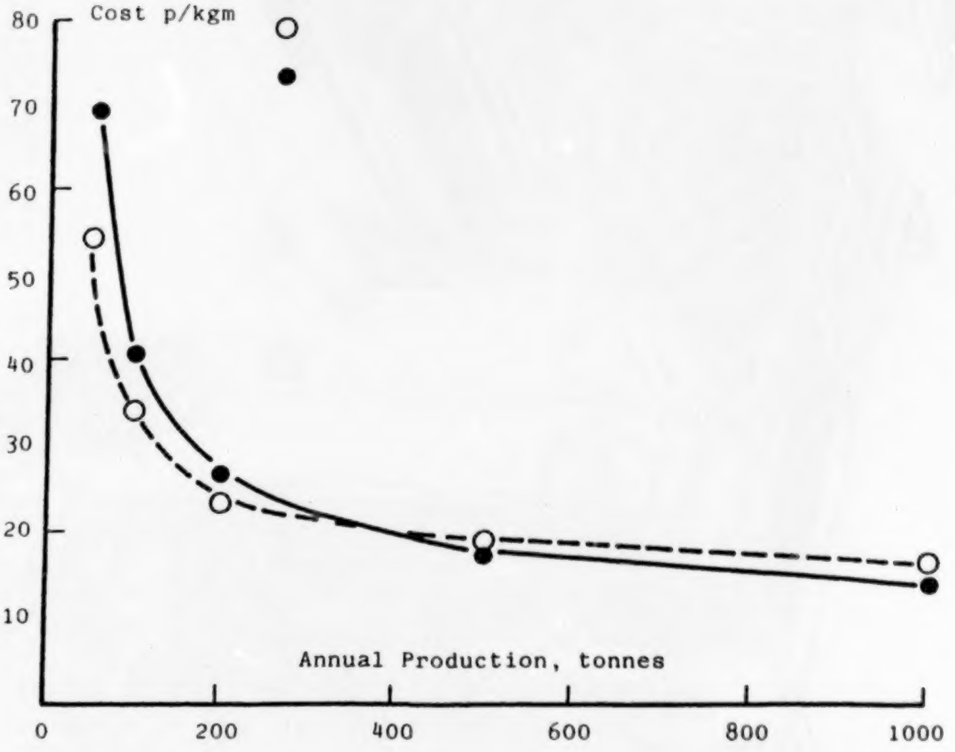
D – Waschpartie
washing section
Section de lavage

Dornier Mercerizing range for Tubular Knitgoods

FIGURE 7

Variation in cost per kgm with Annual Production for mercerising knitted cotton on two machines of different production rates and capital costs.

O Machine A - 250 kgm/hr, Capita Cost £ 85,000
X Machine B - 500 kgm/hr, Capital Cost £120,000



DISCUSSION

MR. G. A. RICHARDSON'S PAPER

Questioned about the possibility of consolidating fabric by multiple squeezing (on the Thies RO machine) in order to achieve specification, the speaker thought it was quite possible, though not a great deal was known about it because of its novelty. The original idea had come from Dr. Carbonnel at Sandoz, he believed, and was very interesting as an aid to chemical treatment (scouring, bleaching, etc). Work done at Meridian indicated that fabric was being compacted during treatment but their main concern was the effect on the appearance and handle of cloth rather than any advantage it was giving by way of producing a more stable cloth.

On the relative merits of bleaching by the Fleissner machine or the Colorado, another questioner was referred back to the speaker's earlier comments about continuous bleaching 20 years' previously using a J-box system. Basically this was the same as that used for woven fabrics and cloth tension was very high. That was why machines for compressively shrinking fabric were introduced and Meridian had started off with the Hunt and Moscrop Bestan machine which again was developed from equipment designed for woven fabrics. When that machine was becoming obsolete it was decided to install a Fleissner continuous conveyor band with suction drum washing. That machine operated at a much lower tension than the old J-box system and so it was a big improvement. Nevertheless, shrinkage performance was still not satisfactory and fabric still had to be compressively shrunk.

The Fleissner was very efficient in terms of operating costs but expensive in terms of capital expenditure - it had cost 1.3 million D marks in 1974/75. Machines like the Colorado would be suitable for the medium size producer who did not have the high production available to put through a machine such as the Fleissner. It would improve operating costs but would not be a cheap machine either. With all the attachments, including a pre-bleach stage before the peroxide, washing, etc. capital cost would be around £150,000. However, operating costs would certainly be much lower than for winch processing and there would be a real opportunity for a medium sized producer to improve fabric quality as well as reduce costs.

All currently available rope processing machines had been assessed very carefully by personnel from Meridian last year. Having run trials on most of these machines, it was felt that with certain fabrics such as fine gauge single jersey there was a danger of rope creasing; with other fabric types there was no problem. In fact, many people running these machines were doing so successfully and satisfying their customers even on the fine gauge single jersey. One had to assess quality requirements for particular markets; they could well be satisfactory for one market and not another.

Developments that had taken place in continuous bleaching had improved performance in terms of lack of extension on fabrics but whether it had improved enough to completely eliminate the problem was doubtful. Even after applying the best available of current technology on the wet processing side, one would probably need to consider some method of improving performance beyond that achievable by mechanical compacting afterwards. Machines such as the Bestan and the Tubetex Compactor behaved quite successfully for most white knitted cottons. The limitations of these machines really started to surface when dyed goods were in demand. Since mechanical compactors exert fairly high pressure on the fabric, the mechanical effect on the surface of a fabric dyed to a fairly full shade would be to reduce depth of shade by as much as 15 - 20%. This was a temporary effect since after washing it returned to its original colour but at the point of sale on the shop counter the colour appeared less full and rich. Thus the growing interest over the past few years in what was commonly referred to as the wet stretching operation followed by relaxed drying.

During wet processing the rounded knitted loop was extended and became long and thin as the fabric became longer and narrower. Wet stretching was designed to overstretch fabric in the width direction and over feed in the length direction in order to reproduce the rounded loop shape and to retain that shape during drying or even to enhance it by passing the fabric through a modern relaxing dryer.

The speaker confessed that he was not really sure what was the relationship between fabric and garment performance - that was one of the questions he wanted to ask Mr. Johansson. Fabric producers were constantly being asked to produce fabrics which had a minimum shrinkage during testing by standard test methods, mostly incorporating tumble drying. So far as he was aware fabric extensibility was not normally a specified test - perhaps it was not always correct to aim for the lowest possible shrinkage.

One must realise, Mr. Johansson commented, that garments had at least two different directions in which to stretch and recover. Width shrinkage was not very critical, he opined; garment and fabric could be allowed to shrink by up to 40% in width and the garment might still be functional. There was no equivalent recovery in the length direction but 7 - 8% length shrinkage would be acceptable provided a garment had been designed to the maximum length from the beginning.

Another questioner wondered why cotton was being used in pure form rather than in a Viloft/cotton blend form and was advised that the blend of Viloft which had been accepted into the knitting industry was a blend with polyester, not cotton. That particular combination had been used in quite large quantities in thermal garments during the last two to three years. So far as market acceptability was concerned for normal standard underwear, customer preference was very definitely for 100% cotton. To achieve a solid dyeing on blended fabrics made from cotton and Viloft was very difficult. It was much easier to control shade in a fibre blend where the two fibre components were dyed with completely different dyestuffs.

The speaker added that cotton/Viloft blends were used for products such as babies nappies - diapers - in terry structures where the moisture absorbency of Viloft was used to advantage. But the big application of Viloft in knitwear had certainly been in conjunction with polyester.

Finally, on garment production, it was noted that in cut and sew operations there were occasions when knitted fabrics were cut on the diagonal or where the garment length was cut from the widthways lay of the fabric. This could indeed cause problems where a fabric might suffer, say, 20% shrinkage across the width, and the only way it could be compensated for would be in the actual design of the garment.

MAKING-UP OF KNITTED FABRICS

Mr. R. Lloyd
English Sewing Limited

INTRODUCTION

It is obviously impossible in such a short time to cover this topic comprehensively. What we propose to do is to consider, from a practical viewpoint, the choices which have to be made to achieve satisfactory seam performance. For the sewing operation itself, we will look at the choices available in seam type, sewing thread and needles and we will also comment on the importance of thread tension and number of stitches per inch. Finally, we will examine in a little more detail one of the commonest problems encountered - sewing damage.

CHOICE OF SEAM

The main objective is obviously to produce a seam not only of adequate strength but also with sufficient extensibility to withstand the stresses likely to be put on it in wear. To achieve this requires first a careful choice of the stitch type to be used, secondly the selection of a sewing thread with appropriate properties and thirdly the insertion of sufficient relaxed thread into the seam.

It is generally accepted that a lockstitch seam (identified in both the European and American stitch standards as stitch type 301) is unsuitable for knitwear because of the inherently low level of extensibility of this stitch type. However, it is not to be assumed that a simple two-thread chainstitch (stitch type 401) is necessarily superior. Indeed it has been demonstrated that for a given amount of seam gape (the opening between the fabric plies which occurs when the seam is loaded) slightly more extension can be achieved with a lockstitch.

To achieve the required level of seam extension a three thread overlock stitch (type 504) is most often used. This not only provides a large amount of thread which is available when the seam is extended but also covers the raw edges of the fabric plies to prevent unravelling and is highly extensible. Other forms of overlocking or safety stitching are not normally used for knitwear as they do not provide the extensibility available from stitch type 504.

Where overlocking is unacceptable because of its bulkiness - for example in a blouse or dress - it is possible to engineer stitch types 301 or 401 to provide sufficient extensibility for such garments by using a relatively high stitch rating (say 12/14 to the inch) and/or high extension threads.

Other types of chainstitch sewing are of course also used on knitwear. Where bindings have to be attached to leg openings or elastics applied to waists in underwear, stitch type 406, seam cover stitch is used. This consists of two needle threads which are interlooped with one looper thread. The cover stitch is also used on occasion in knitwear to cover three thread overlock stitched seams. Other flat seams are also produced for underwear where fabrics are required to be joined edge-to-edge. These contain a number of needle and looper threads with and without additional cover threads on top or underneath. Two common ones are the 'flatlock' stitch type 606, which contains four needle threads, four looper threads and one bottom cover thread and the 'flatseam' stitch, type 607, which has four needle threads but only one looper thread and one cover thread.

CHOICE OF THREAD

Turning now to sewing threads, the 'correct' choice for a knitted fabric is obviously one which will provide adequate performance in terms of both seam strength and extensibility as well as good sewing properties. Comfort in wear may also be a requirement particularly where skin contact seams are involved. Finally it is often necessary to use fine needle sizes for knitwear and this means that threads with high strength in relation to their size are essential.

Because of these factors synthetic threads now predominate in Europe usually in the form of core spun polyester/cottons or straight forward 100% spun polyesters. There are also some polyester/polyester core spuns available. Polyester/cottons are often favoured because of their excellent sewing properties particularly in adverse situations such as high needle temperatures. Spun polyesters however are also extensively used although their sewing properties are perhaps a little more variable on some operations and their extensibility is slightly lower - 17/18% at break compared with the core spuns 20%. Spun polyesters do provide excellent seam strength however usually slightly more than core spuns size for size.

Specialised high extension 100% synthetic threads are sometimes available but the other most common thread in the UK particularly is the so called bulked thread. These are produced from false twist nylon or polyester yarns - usually nowadays the latter. Their higher 'loft' makes them attractive as looper threads to provide soft seam texture and high cover. In order to maximise these effects it is essential to sew them in under the lightest possible tension. Indeed the drag produced by passage over the guides and stitch forming parts of the sewing machine may provide sufficient control without the need to pass the thread through the disc tensioner.

The size of thread used for knitwear obviously varies according to the fabric weight and the stitch in use. 'Sizes' of sewing threads are usually identified by a ticket number which in Europe in the case of synthetic threads is related to the nominal metric count of the input yarns. (The number of hanks of 1,000 metres in one kilogram). All threads are treated as if they were of three cord construction no matter how many yarns are actually used so that the ticket numbers are all comparable. The system is explained more fully for those who are interested in British Standard 4134:1982.

For heavy-weight knitted fabrics ticket number 75 or 80 is used while for medium and light-weights number 120. Bulked looper threads are usually number 80 but a finer size number 160 and a heavier size number 40 are also available.

STITCH DENSITY AND THREAD TENSION

The strength and extensibility of the thread do not however on their own establish the seam performance to be expected. Two other factors both related to the sewing conditions are equally important. To achieve sufficient seam extensibility requires sufficient thread to be present in the seam and it must be sufficiently relaxed. That is to say there must be an adequate number of stitches per inch or per centimetre to allow the seam to extend to the required level and to give it sufficient strength to last the expected life of the garment. We would suggest a minimum of 12 stitches per inch is required. Secondly the threads must be sewn in at a tension setting which will give good stitch formation without stretching the thread unduly and producing seam cockle. Tension settings should however not be too light or unacceptable seam gape will appear.

SEWING DAMAGE

No discussion of seaming techniques for knitted fabrics would be complete without some consideration of the problem of sewing damage. Obviously avoidance of needle damage depends in the first place on proper needle selection. In other words it is important to use the finest possible needle size in relation to the weight of the fabric, the thickness of the seams and the size of the sewing thread. With a 120s thread on lightweight cloth such as fine jersey one should aim for a number 70s (Singer number 10s) needle while with a 75 or 80s thread on heavier weight cloths 90s or in exceptional circumstances an 80s needle is appropriate. It should not be necessary to go heavier than these latter sizes.

Needles are available with different types of point and selection here can be significant for correct sewing of knitted fabrics. The normal round point used for sewing wovens is not usually appropriate for a knitted cloth as it will tend to cut the fabric yarns. Needles have therefore been produced with more rounded points usually referred to as ballpoints which tend to push the fabric yarns apart to permit penetration rather than punching their way through. The degree of rounding varies and there are light, medium and heavy ballpoints available. For most circular and warp knit fabrics a light ballpoint (usually identified as SES) is usually successful with a medium ball (SUK) for heavier cloths but we would advise experimentation in each instance to establish the most suitable type of point.

The correct initial choice of needle is not the end of the matter however. That needle has to penetrate the cloth and descend through the throat plate of the machine so that the stitch can be formed. It is therefore very important that the throat plate hole is of an appropriate size for the needle in use. A large hole will result in the fabric tenting or flagging - that is being pushed below the throat plate and becoming damaged as a result.

Since fine needles have to be used there is always a danger that they may be more easily deflected. To overcome this problem flow pressed needles have now been introduced which has the effect of increasing the bending stiffness so reducing deflection.

In addition it is essential that all the machine parts in the sewing area should be in good condition; there should be no chips or grooves which could damage the cloth. This applies to the feed, throat plate, the presser foot but most of all obviously to the needle itself. It is vitally important that needles are changed regularly and by regularly we mean at least once per day - it has been known for hourly changes to be suggested but this is only exceptionally required.

Finally it is important that the fabric is stored in suitable conditions. Cloth kept in a very dry atmosphere can be brittle and we have demonstrated this particular problem by applying some steam to a cloth which had been giving needle damage trouble. Immediately we were able to sew without damage.

All of these recommendations are obviously aimed at enabling the garment producer to overcome or minimise needle damage problems. In our opinion the sewing properties of the fabric should always be considered when considering the finishing to be employed. Clearly the finish should contain some kind of sewing lubricant to ease the passage of the needle but the presence of such lubricant does not guarantee freedom from damage if the cloth contains other materials (e.g. silicate residues from bleaching,fillers) which increase inter-yarn friction. In this situation the fabric yarns are less free to move and movement is essential if needle penetration is to be effected without damage to the cloth. We appreciate that we are asking for a rather subtle compromise to be achieved so that the benefits of finish in terms of crease resistance for instance are achieved without prejudice to its sewability.

So far we have been considering mechanical damage to the fabric. Where synthetic fibres are involved thermal damage can also occur - needle temperatures very readily reach levels above the melting point of most synthetic fibres. The presence of sewing thread helps to reduce that temperature and the effect of the sewing thread lubricant can also help in this respect. In particularly severe conditions however the introduction of some additional lubrication to the needle can be helpful. This can be achieved either by spraying lubricant via an air line either directly onto the needle or onto the fabric immediately prior to the needle or by applying more lubricant to the sewing thread by passing it over a pad which must be placed after the tension disc. Obviously in this sort of situation polyester/cotton core spun threads are preferable to any other type of synthetic.

CONCLUSION

To sum up, an extensible stitch is essential for knitted fabrics and for that reason the three thread overlock is the most common type of machine used. Other types of chainstitch are also used for particular garments to give seam cover and to permit edge to edge joining. Sewing thread ideally should be synthetic to provide the strength in relation to fineness and the essential extensibility. Specialist looper threads are available in the UK to give a soft seam texture for next to skin wear. Seams should be produced with an adequate number of stitches per inch to give the strength and extension needed and tension should be set so that the thread is stitched in relaxed.

It is important to pay particular attention to the condition of the machine parts, particularly in the sewing area, and to ensure that the needle size and point type are appropriate for the fabric to be sewn. Needles should be changed on a regular basis to ensure that unnecessary damage does not take place. Where needle heating problems are encountered, additional lubrication of the fabric immediately prior to the needle or additional lubrication to the thread can help alleviate the problem. Ideally fabrics should be finished with an eye to their sewing properties but in some cases compromise may be necessary.

DISCUSSION

MR. R. LLOYD'S PAPER

Responding to a question about standards relating to coefficient of friction in sewing, the speaker said that obviously the aim was to get good stitch formation at minimal tensions. There would be variation between manufacturers as well as variations induced by colour and other processing inputs but his company had a product designed to give a range of frictional coefficients which were subjected to strict quality control checks.

The speaker agreed that a sewability test would give some idea of frictional property; they were required to do sewability tests by the major chain stores who set the standards in this respect. These involved stitching a set number of thicknesses of cloth to a set number of revolutions on the machine and measuring the number of faults per length of cloth sewn over a long period. These were minimal tests; the sewing thread supplier tested over a wider range of machinery on more critical fabrics using other tension and sewing measurements to indicate the sewing performance of the thread and fabric.

The commercial objective was to get the maximum versatility from one range of threads. That was why the speaker's company had concentrated on cotton/polyester corespun thread, because it had been found it gave wide ranging applicability. The only area it could not be applied to in the UK was for 100% synthetic nightwear where 100% synthetic thread was required by government decree.

One of the speaker's jobs was to visit factories to look at the range of sewing operations as well as the cloths involved, including trimmings, and to establish how far one could compromise in terms of thread size in order to minimise the numbr of threads in use. It was not always an easy decision to make, but the corespun thread did by and large give a high performance standard with the 120s size offering the maximum coverage of cloth types.

Asked whether one might buy corespun thread and dye it up afterwards, he said it would depend upon the cloth to be sewn, its fibre content and the dyestuffs to be used. A number of people in the UK were experimenting with garment dyeing to offer quick fashion response. Usually in those instances there was a need for compromise; often it had been found that nylon sewing threads were more suitable and one might perhaps have to accept a lower standard of sewing performance because with the corespun, of course, there were two fibres to dye, cotton and polyester.

DESIGNING WELL FITTING GARMENTS

Bernt Johansson
TEFO

Garments referred to in this paper are closely fitting garments such as:

- undershirts, covering the upper part of the body
- underpants, covering the lower part of the body
- overalls, covering the whole body

Many factors can influence the fit of a garment. TEFO has developed a unique know-how in this field. In my paper I will describe our way of thinking and methods of testing when developing a garment with good fit.

One way to approach this subject is to try to design an actual garment. I have chosen a singlet, i.e. an undershirt without sleeves, this type of garment being the least complicated one, since there are only a few critical garment measurements to deal with. Garment measurements are critical if they influence the customer's judgement of the fit.

In the TEFO-method these garment measurements are always compared with critical body measurements.

The comparison is made on new garments, but also on washed and dried garments. Drying includes flat, line and tumble drying.

SIZE

The first and most fundamental factor to notice is the control dimension and size intervals. All other factors involved are dependent on this.

Swedish manufacturers of knitted garments are advised, in a Swedish standard, to use one of the following ways to indicate size:

- chest girth interval
- an established and well defined code-number based on chest girth
- bodyweight
- height (children and young people)

This piece of information is also very important to customers, as they normally make their choice without trying on the garments. The only one to gain something by using "small, medium and large" labels is the manufacturer of badly fitting garments. The singlet is intended for the grown-up male population. Let us choose chest girth as the control dimension. For men chest girth varies between 86 and 126 cm. The size interval of 8 cm gives the following 5 sizes:

86 - 94
94 - 102
102 - 110
110 - 118
118 - 126

Potential customers have now been divided into five separate groups. Every member of a group choosing the right size should find a well fitting singlet.

CRITICAL GARMENT MEASUREMENTS

TEFO has undertaken a wide investigation to establish critical garment measurements for all the types of garments mentioned earlier. For the singlet the following measurements are critical:

- width
- length
- arm-hole width
- neck width

WIDTH

The shirt will be produced with a constant width along its length. This means that the fabric is knitted on a body-width machine or the panels are cut straight.

If fashion does not dictate otherwise most users want the shirt to fit tightly to the body, including the waist.
It is therefore necessary to know the relation between control dimension and waist girth.

TEFO has undertaken extensive investigations of body measurements for the Swedish population. Measured data have been stored in a computer.

So far there is no reason to believe that the body proportions of the Swedes differ significantly from other people. The data base is therefore useful in almost any country. The distribution among sizes, however, varies from country to country.

The print-out of chest girth and waist girth for men is presented in figure 1.

This type of diagram can be printed for every critical body measurement.

The solid line represents the average. The dotted lines enclose 96% of the population, i.e. twice the standard deviation. This form of statistical analysis meets the target of the TEFO-method to satisfy at least 96% of the population.

In figure 2 the chosen size intervals are marked by vertical solid lines. In each size the waist girth varies between a minimum and a maximum value.

This procedure is applied to all body measurements.

It is now possible to create two fictional characters - Mr. Min and Mr. Max. (They can be women or children). The former has all the minimum body measurements and the latter the maximum values. If Mr. Min and Mr. Max are satisfied then all others are satisfied. To fit closely, the garment width must be narrower than Mr. Min's waist girth. This can be read off from figure 2.

Concentrating on size 102-110 the sought-for value is 85 cm. This is the upper limit for the width and it must not be exceeded during the garment's service life.

STARFISH is of great value in assisting the knitter to pick the right combination of:

- knitting machine
- knitting parameters, stitch length and yarn count
- finishing specifications

to meet this width requirements.

When it is put on the singlet must adapt itself to Mr. Max's chest girth. For size 102-110 this is of course 110 cm. This is achieved by straining the garment in width. If the straining tension is less than 0,25 N/cm then the majority of users will accept the pressure to the chest from the shirt.

Testing the width is performed in two steps.

STEP 1. The width is measured with a tape with the garment lying flat on a table. The measurement is compared to Mr. Min's waist girth.

STEP 2. The strained width is measured with the "Width Extension Gauge" (figure 3). The garment is pulled outside the two semicircular-shaped side extenders. The width is extended by one of the extenders moving horizontally under a fixed loading. The load gives the tension 0,25 N/cm.

THE LENGTH

In wear a knitted garment usually decreases in length and extends in width. This means that measuring the length of a closely fitting garment lying flat on the table will give no relevant information.

Therefore TEFO has developed the "Shirt Length Gauge" (figure 4). The apparatus can be set to circumferences corresponding to all existing chest girths. This is achieved by moving the vertical plate on the right hand side along a scale and locking it in a predetermined position.

Once again, this test will show whether Mr. Min and Mr. Max are satisfied.

Mr. Min is given the smallest chest girth of the size and Mr. Max the largest one.

The shirt is pulled over the plates and the apparatus is set to these circumferences. The shirt length is measured with a tape for each of the two settings.

The acceptable length is determined by the vertical trunk girth. A large number of tests has shown that a shirt must not be shorter than 35,5%

and not longer than 43% of this body measurement.

Returning now to the singlet in size 102-110. The vertical trunk for Mr. Min = 156 cm and for Mr. Max = 188 cm. Mr. Min says that the longest acceptable shirt is

$$0{,}43 \times 156 = 67{,}1 \text{ cm}$$

Mr. Max says that the shortest acceptable is

$$0{,}355 \times 188 = 66{,}7 \text{ cm}$$

There is no rule without exceptions, and here is one.
The requirements must be realistic and this one is absolutely not. It was found necessary to lower the level of acceptance to satisfy 67% of the population. This gives the following trunk girths:

Mr. Min = 164
Mr. Max = 180

leading to the following limits for shirt length:

shortest	longest
63,9	70,5

If the singlet is designed to the maximum length then the difference from this due to variation in manufacturing and washing shrinkage may total - 6,6 cm or -9,4%. This seems to be a realistic design target.

Once again STARFISH can assist the manufacturer to specify courses or weight after finishing to meet the length shrinkage requirements.

Those outside the 67% acceptance limit who find the new shirt is too long will be satisfied after the first washing cycle if the length shrinkage is 5%.

Those finding it too short will, as before, have to buy too-large sizes and their situation is neither worse nor better.

A quality-conscious manufacturer, and who is not, ought to produce the shirt in two different lengths in each size to satisfy more customers.

ARM-HOLE WIDTH

Pressure against the armpit is not acceptable. This implies that the arm-hole width must be larger than Mr. Max's arm-scye girth.
For size 102-110 this body measurement is 57,0 cm.

Arm-hole width can be measured with a tape along the folded edge or the seam. The easiest way is to use the "Width gauge" (figure 4).

This device is actually used to measure all kinds of garment openings.

It has two shanks, the upper one fixed. The lower one is vertically moveable along a scale. Half the opening width is read off the scale.
The weight of the lower shank gives the load 1 N. Extra weights are hung on the moveable shank if needed.

NECK WIDTH

The neck opening must be large enough to prevent the garment exerting pressure against throat and neck.
The opening width is determined by Mr. Max's neck girth. For the actual size it is 45 cm.

When the garment is put on, the neck opening is pulled over the head. The extended opening must be larger than Mr. Max's head girth, i.e. 61,5 cm.

The TEFO testing is carried out in two steps, using the width gauge. In the first the load 1 N, and in the second 15 N, are used. The readings are compared with Mr. Max's neck girth and head girth respectively.

CRITICAL GARMENT MEASUREMENTS

Table 1 presents all critical garment measurements and the corresponding body measurements for the types of garments in question.

TABLE 1

Shirts, covering the upper part of the body

Critical garment measurements	Corresponding critical body measurements	Without sleeves	Short sleeves	Long sleeves
Length	Vertical trunk girth	x	x	x
Waist width	Waist girth	x	x	x
Chest width	Chest girth	x	x	x
Arm-hole width	Armscye girth	x	x	x
Upper sleeve width	Upper arm girth		x	x
Lower sleeve width	Min. fore-arm girth			x
Sleeve length	Arm length			x
Neck width	Neck girth	x	x	x
Neck width	Head girth	x	x	x

Pants covering the lower part of the body

Critical garment measurements	Corresponding critical body measurements	Without legs	Short legs	Long legs
Waist width	Waist girth	x	x	x
Buttock width	Buttock girth	x	x	x
Height	Waist-Crotch-Waist	x	x	x
Thigh width	Groin girth	x		
Thigh width	Thigh girth		x	x
Lower min. leg width	Lower min. leg girth			x
Leg length (inside)	Crotch height			x

Overalls, covering the whole body

Critical garment measurements	Corresponding critical body measurements	Without sleeves and legs	With sleeves and legs
Trunk length	Vertical trunk girth	x	x
Chest width	Chest girth	x	x
Waist width	Waist girth	x	x
Buttock width	Buttock girth	x	x
Arm-hole width	Arm-scye girth	x	x
Sleeve length	Arm length		x
Upper sleeve width	Upper arm girth		x
Lower sleeve width	Min. fore-arm girth		(x)
Leg length (inside)	Crotch height		x
Thigh width	Groin width	x	
Thigh width	Thigh girth		x
Lower min. leg width	Lower min. leg girth		(x)
Foot length	Foot length		(x)

TESTING DEVICES

There are some further testing devices to describe.

TEMPLATES FOR PANTS

The template (figure 6) has measurements based on the average person in each size.

This device is used to measure garment height while extended widthwise.

The pants are pulled over the template and two small weights are attached to the waistband. They will stretch the garment in length in the same way as when worn.
The back and front height is read off a scale on the template. Both the sum of the heights and the difference between these are critical factors for good fit.

TEMPLATES FOR OVERALLS

A combination of one template for pants and one for the upper part of the body is used when measuring the vertical length of overalls (figure 7)

The template for the upper part of the body will have been lightened, if necessary, to give the right weight. The overall is pulled over the two templates and placed on a table. The distance between crotch and shoulder is measured with a tape. The garment is then inverted, letting the "upper" template extend the length. The same distance is measured again.

The garment measurements are compared with the trunk girth of Mr. Min and Mr. Max respectively.

THE RACK

Closely fitting garments require a certain amount of stretchability as do the fabrics from which they are made, of course.

TEFO has developed a fabric tester called the "Rack" (figure 8). On this apparatus the width extension of a tubular test piece is measured under a given load. The load is calculated from the knowledge that 0.25 N/cm is the highest acceptable tension.

Simultaneously the length decrease due to width extension can be measured. The results from the rack can be used to develop and select fabrics that will meet garment requirements.

SUMMARY

The most important factors to consider when designing a closely fitting garment are thus:

- to use a quantitative size designation. It is necessary for the designer to have well defined target groups. It also enables the customer to choose the right size.

- to optimize the size intervals in relation to the number of sizes required and the extensibility of the fabric.
  In size 86 - 94 Mr. Min's waist girth is 67 cm and Mr. Max's chest girth is 94 cm. The extensibility must be at least

$$\frac{94 - 67}{67} \cdot 100 = 40\%$$

- to define all critical garment measurements for the garment type

- to establish the relationship between control dimension and all critical body measurements, i.e. to invent Mr. Min and Mr. Max

- to fix the demands for good fit, e.g. the limits of acceptable pressure exerted on the body

- to test the fabric properties - washing shrinkage and extensibility

- testing of the garment is performed on the TEFO equipment. The results are compared with Mr. Min and Mr. Max derived from TEFO's body measurement lists. This is a much easier way than establishing a panel of people to test the garments. The test panel must contain extreme body measurements in each size to guarantee a good fit for everybody.

TEFO has all the necessary know-how and we are ready and willing to help you develop well fitting garments.

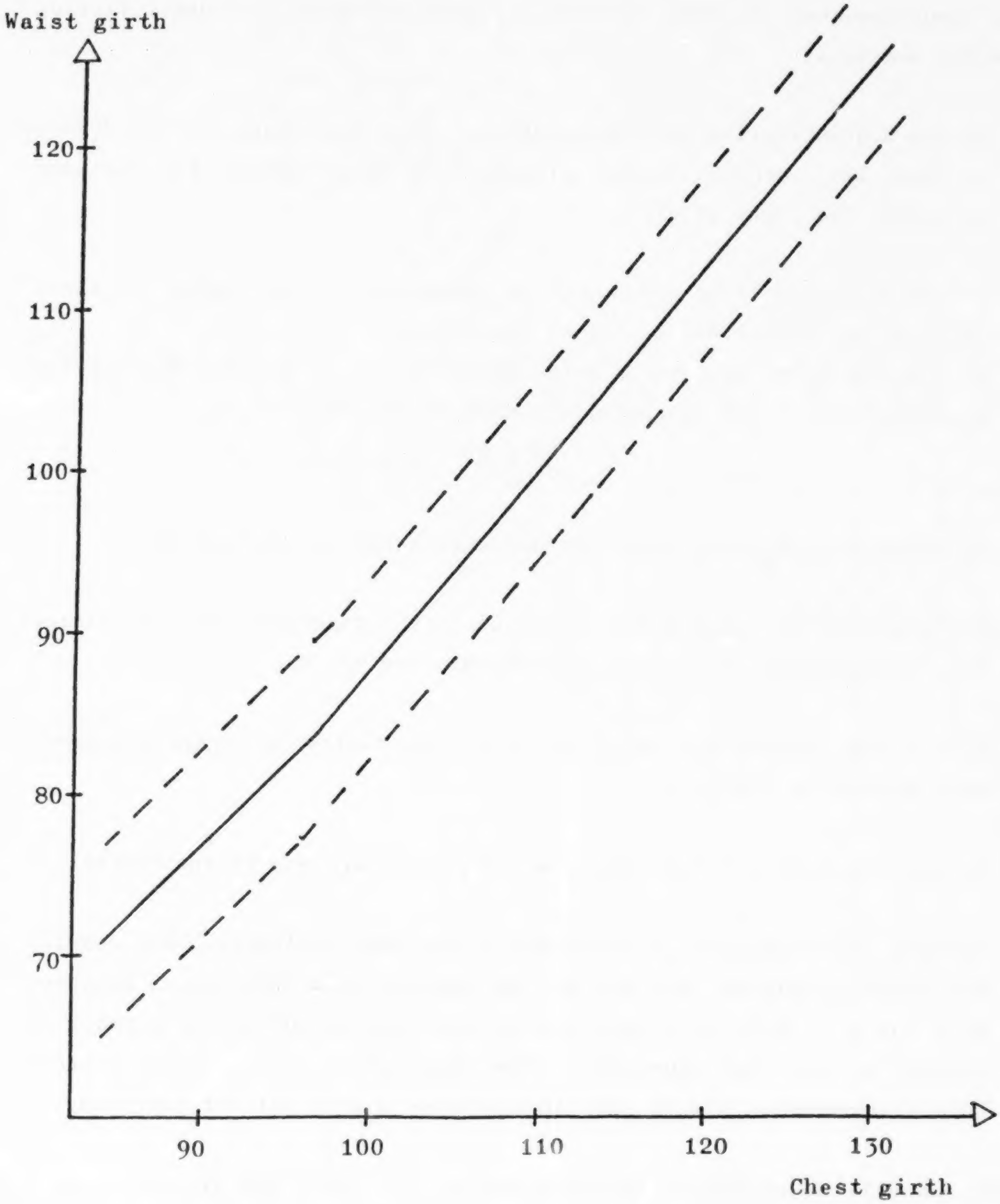


Figure 1.

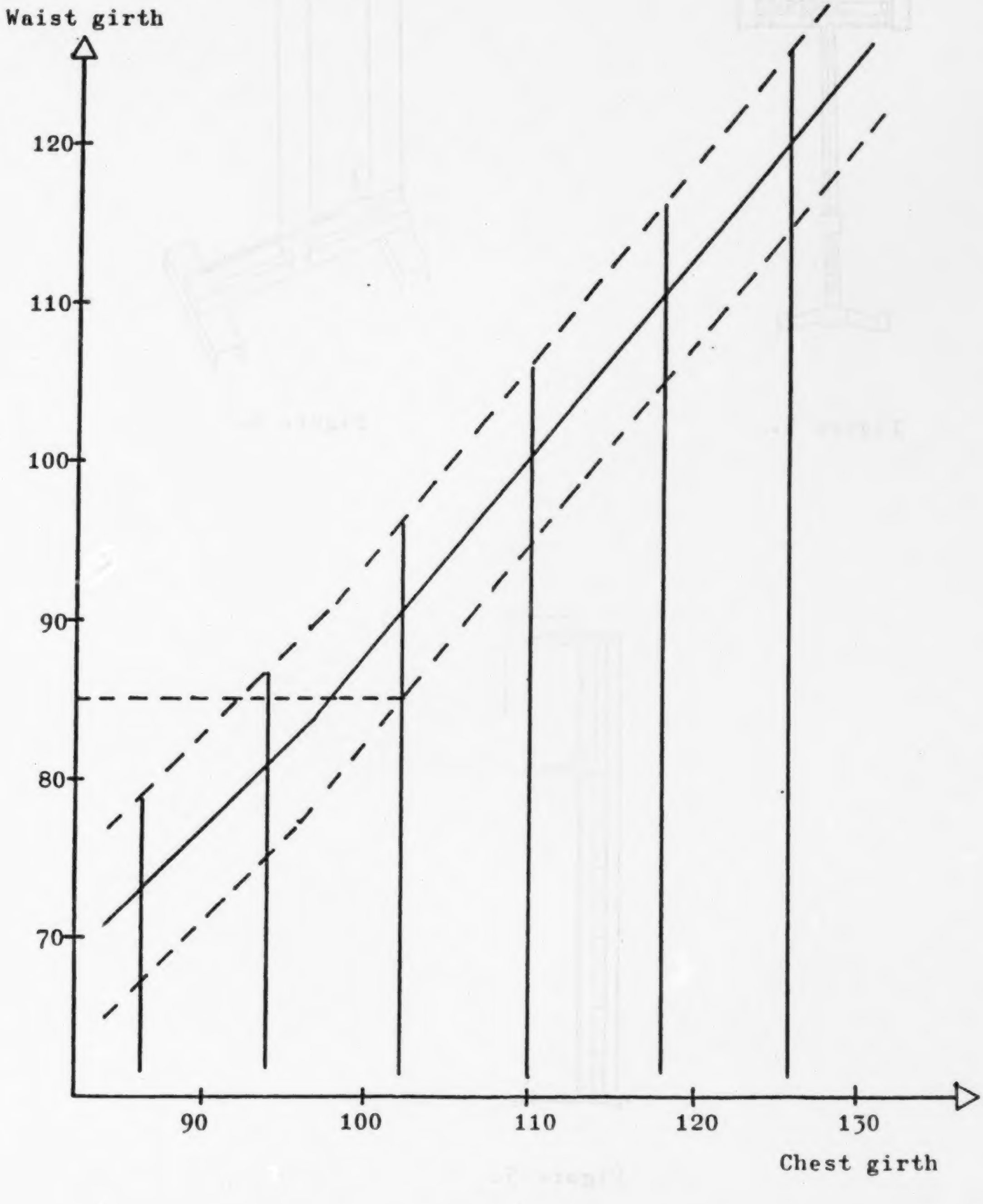


Figure 2.

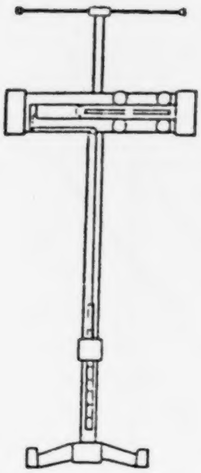


Figure 3.

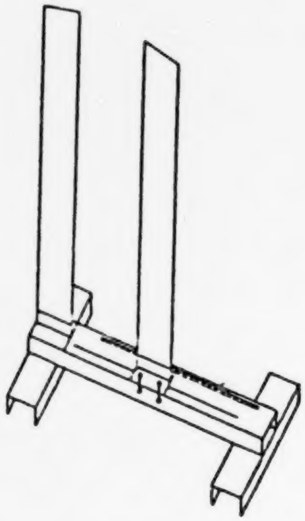


Figure 4.

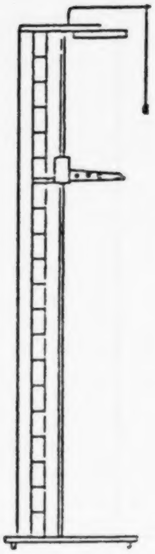


Figure 5.

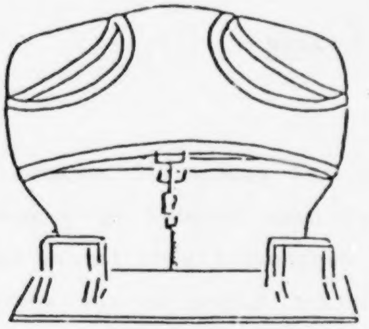


Figure 6.

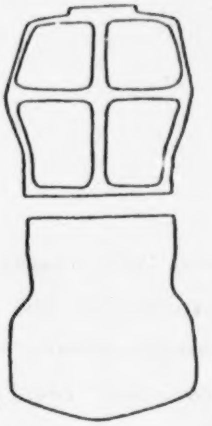


Figure 7

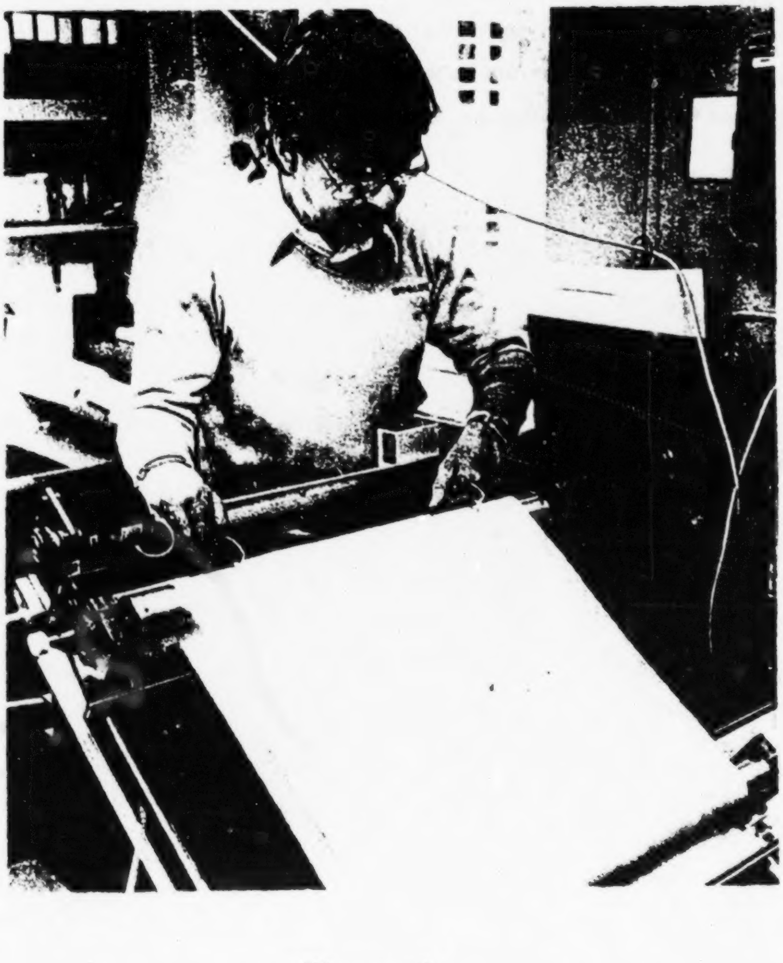


Figure 8.

DISCUSSION

MR. B. JOHANSSON'S PAPER

Asked about the commercial application of the system of garment sizing he had described, the speaker said it had been adopted by a number of Swedish manufacturers and retailers, very successfully as far as he knew. As for consumer reaction, the only important thing to the wearer was whether a garment fitted as new, and after a number of wear/washing cycles.

There was in effect only one parameter to consider, chest girth or body weight. The point was stressed that it was difficult to see why "small, medium and large" had been used as descriptions as garment sizes. The designer of the garment needed to know the measurements of his target group, so why not include these on the garment label?

DISCUSSION

RECENT DEVELOPMENTS IN KNITGOODS MACHINERY AND PROCESSING

Mr. T. Marns, ICI Organics Division
Mr. J. T. Littleton, Bentley Engineering Co. Ltd.
Mr. D. J. Catlow, Rockwell-Rimoldi (GB) Ltd.
Mr. W. E. A. Shelton, Alan Shelton Ltd.

On the subject of enclosed yarn creels for knitting, Mr. Shelton was asked what contribution was made by the use of moisture in his creels as compared with blowing loose lint off the yarn supply. He believed they both played a part, although until the correct conditions of humidity had been established inside the cabinet the blowing away of lint was not relevant. Cotton yarn usually had a 5 - 6% moisture content when it was removed from the supply carton. By holding it in the high humidity of the creel cabinet at the time of knitting it would absorb a further 2 - 3% of weight by water, which he believed to be the real factor inhibiting the shedding of lint. Added to that was the mechanical removal of lint from the cones and various other parts, but the humidification was important.

Another questioner wanted to know if the speaker had examined the effects of high humidities on the frictional properties of waxed cotton yarns because all the work done so far showed that these were higher for high humidity as opposed to standard humidity. He was told that no direct work had been done on that subject. The knitter had to deal with yarn as it came from the carton and inevitably there would be varying amounts of wax present. However, their best success had been with unwaxed yarns, including open end yarns.

Asked what advantages would stem from using high humidity with synthetic fibre yarns or blends of synthetics and cotton, the speaker said he thought most synthetic fibres would absorb some moisture - not as much as natural yarns like cotton and wool - and a certain amount of moisture was very beneficial in reducing or minimising static. When this statement was challenged he agreed that the synthetics absorbed tiny amounts by comparison but it was certainly true that in a dry atmosphere one would suffer from higher static problems. When it was suggested that the use of the correct lubricant with an antistatic in it would take care of static problems the speaker pointed out that that was an expensive addition; moisture was much cheaper. Historically, yarns were conditioned in a conditioning cabinet prior to processing. What he had done was to build a conditioning cabinet around the creel. "We have created a little bit of Manchester around every cone of yarn," he added. "It seems not a bad idea."

Much of the questioning at this stage of the seminar was reserved for Mr. Marns whose presentation on pad batch dyeing involving the use of reactive colours and beam washing stimulated quite an animated discussion.

Asked at the outset about fastness characteristics of fabrics so processed using grey fabric, he admitted that he had not made a direct fastness comparison but many tons of fabric had in fact been dyed on an unprepared base and fastness levels achieved had certainly been satisfactory. Judged in terms of an ISO 3 wash test, the effect on shade was of the order of 4 to 5 and no differences had been observed between prepared and unprepared fabrics. Obviously there were limitations in terms of brightness and depth of shade that could be achieved, and there was always the problem of cotton seed.

Dyestuff migration was also referred to and the speaker was asked to indicate the fabric weights that could be accommodated on a beam. He said it depended on whether fabric was in open width or tubular form but the range was from 200 to 400 kilos. Migration was prevented by wrapping the batch in polythene. It had never been a problem in pad batch because the batch was prevented from drying out. In fact it would be very difficult to control migration of a reactive dye if it ever did become a problem but the use of salt perhaps and a little thickener might help. One of the important parameters of a pad dyeing process was not to overload fabric with dye liquor. On cotton knitgoods the pickup would be 110 to 120%; and at these levels it was necessary to rotate the batches very slowly.

He emphasized the simplicity of washing; no soap only water. When washing-off the unfixed dye the most important factor was temperature. Starting with cold water to remove the easily removable dye liquor, the temperature of water being pumped in would then be raised to 90 - 95°C. To get the difference between a 3 and a 4 on the ISO scale required time and temperature, but temperature was the important factor. Typically 400 kilos of single jersey fabric could be washed-off in about 2 to 2½ hours.

With beam washing any depth of shade could be washed-off because all one had to do was to extend the time on the beam. On the other hand with a continuous washing range, if the machine was not long enough then it would need to be reloaded and the fabric put through once more. With a beam washer the time could easily be extended to cater for a difficult shade or shortened for a pale or easily washed-off shade. Thus the system was very flexible and it was far cheaper to buy a beam washing system than a continuous washing range.

Another possibility that could lead to unevenness of shade, particularly in hot humid countries, was neutralization of the caustic alkali by atmospheric carbon dioxide. This occurred mainly at the fabric edges.

A means of minimising if not overcoming the problem was to use a mixture of caustic soda and sodium silicate. ICI's competitors had to use that system as a means of fixing their dyestuffs. It did not eliminate the problem of CO_2 absorption completely but it did minimise it. ICI were fortunate in that their dyes were more reactive than any other range and therefore soda ash could be used to fix them; this sytem was less susceptible to carbon dioxide absorption. For temperature climates he would recommend the use of soda ash only; for a hot climate a mixture of sodium bicarbonate and sodium carbonate might give the right conditions of stability.

Owing to lack of time the speaker had been unable to refer to the laboratory control aspect of pad batch dyeing but in response to further questioning he conceded that this was the most crucial and important part of the whole process. If the shade was not quite right at the end of processing by winch or jet, a shade addition could be made while the fabric was still in the machine. With pad dyeing if the shade was wrong the fabric had to be reprocessed. So it was important to have a reliable laboratory testing technique to simulate what happened in the bulk. The laboratory procedure involved the use of a small mangle which was designed to give a performance which matched as closely as possible that of the full scale mangle. A technique had been developed whereby fixation could be achieved at an elevated temperature in a very short time. For example, 20 minutes at 50°C would give a very close approximation of what one would get by batching for four hours. These small scale trials were carried out using the liquor which had been prepared for the bulk processing.

The speaker was asked how critical was the speed of padding? He replied that provided the fabric wetted out quickly, a processing speed of 40 metres a minute was commonly used for both tubular and open width fabrics. There was no apparent reason why one could not run faster but he would begin to get concerned if production speeds declined because of the dangers of 'tailing' and other hydrolysis problems.

Pickup was determined by the hardness or softness of the bowls but the nip pressure could be varied. Acceptable levels of pickup were higher for knitgoods than one would use for woven fabric. In fact on greige, unprepared fabric, with the use of auxiliary chemicals, pickup levels as high as 140 to 150% were being obtained, without any problems provided the batches were rotated to stop seepage.

A useful instrument (made by PLEVA) to measure pickup was mentioned by one delegate.

The speaker was asked whether he had had any experience of pad batch processes being used for mercerised knitgoods. He regretted that he had no such experience but he thought the fabric would need to be close to neutral after mercerisation.

Asked about the prospects of changing machine gauge on the Bentley Variknit machine, Mr. Littleton said one could change the gauge as well as camming. He had mentioned earlier that the cylinders could be taken out from below the machine so as not to disturb the top structure, but clearly a wise initial choice of gauge was desirable.